Attachment C

Navajo Dam and Reservoir Operation Report for the Animas-La Plata Project

Attachment C to the ALP Project Final Supplemental Environmental Impact Statement presents updated information of the operation of Navajo Dam and Reservoir as it relates to the ALP Project. Operation of Navajo Dam and Reservoir is a connected action to the ALP Project and other water resource activities in the San Juan River Basin.

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NAVAJO DAM AND RESERVOIR OPERATION REPORT FOR THE ANIMAS-LA PLATA PROJECT

1.0 INTRODUCTION AND BACKGROUND

The Department of the Interior, through the Bureau of Reclamation (Reclamation), in cooperation with the United States Environmental Protection Agency (EPA) and the Ute Mountain Ute Tribe and Southern Ute Indian Tribe (Colorado Ute Tribes), has prepared a Final Supplement Environmental Impact Statement (FSEIS) for the Animas-La Plata Project (ALP Project). This attachment to the FSEIS presents updated information of the operation of Navajo Dam and Reservoir as it relates to the ALP Project.

1.1 Connected Actions and NEPA Compliance

Operation of the Navajo Reservoir is a connected action to the ALP Project and other water resource activities in the San Juan River Basin, such as the Navajo Indian Irrigation Project (NIIP). These connections stem from:

- ❑ Past Endangered Species Act (ESA) consultations which established and relied upon the San Juan River Basin Recovery Implementation Program (SJRBRIP) and listed certain Reasonable and Prudent Alternatives (RPA) to avoid jeopardy to the endangered species in question;
- ❑ San Juan River flow recommendations developed and approved by SJRBRIP in 1999;
- ❑ The 1999 ESA consultation for NIIP, including operation of Navajo Reservoir to meet these flow recommendations as a project element; and
- ❑ Reclamation’s previous commitment to operate Navajo Reservoir for the benefit of endangered fish in the San Juan River Basin as requested in the 1991 and 1995 Biological Opinions as part of the RPA for the ALP Project.

Consideration of Navajo Reservoir operation issues and impacts (e.g., flow regimes, riparian impacts, reservoir levels, reservoir recreation issues, trout fishing, and habitat issues) are addressed in this report.

1.2 Relationship to the Animas-La Plata Project

On May 7, 1990, the U.S. Fish and Wildlife Service (Service) issued a draft Biological Opinion concluding that the ALP Project would jeopardize the continued existence of the Colorado pikeminnow (formerly called Colorado squawfish). No RPA was identified. In subsequent Section 7 consultation, a RPA was developed that requested operation of Navajo Dam mimic a natural hydrograph for the life of the ALP Project. This RPA to a Jeopardy Opinion was included in the October 25, 1991 Biological Opinion. Since the specifics of how to mimic a natural hydrograph were not quantified for the San Juan River, the RPA included a commitment to contribute funding for approximately seven years of research to determine the flow requirements of the endangered Colorado pikeminnow and razorback sucker (at the time a candidate species that received endangered status on October 23, 1991). The Opinion that a commitment to future operation to mimic a natural hydrograph was adequate without quantifying the water necessary to achieve mimicry was based on modeling work completed by Reclamation. The modeling indicated that sufficient water was available given the baseline depletion to provide a 300,000 acre-foot (af) release for fish in 96 percent of the years. This was not specified as a release requirement, but reflected availability of water sufficient to meet any likely scenario. In exchange for this commitment, the ALP Project was given an initial average depletion allowance of 57,100 acre-feet/year (afy).

Prior to the issuance of the October 25, 1991 Biological Opinion, Reclamation requested initiation of Section 7 consultation on the operation of Navajo Dam in a memorandum to the Service dated July 30, 1991. In that memorandum, Reclamation committed to operate Navajo Dam in concert with ongoing research to determine hydrologic conditions for the fish and thereafter to operate Navajo Dam in a manner most consistent with endangered fish recovery, for the life of Navajo Dam It was also recognized that Reclamation would produce the necessary documents to comply with the National Environmental Policy Act (NEPA) on any recommended changes to the operating criteria for Navajo Dam. On August 19, 1991, the Service concurred with Reclamation's request and extended the consultation period to allow completion of the research.

The 1991 Biological Opinion on the ALP Project also required the dam to be operated to provide test releases during the seven-year research period, under the direction of the SJRBRIP Biology Committee. Navajo Dam has been operated in this manner since 1992.

On February 26, 1996, a second biological opinion was issued in relation to critical habitat, confirming the commitment to operate Navajo Dam to mimic a natural hydrograph for the life of the ALP Project. Further restrictions were placed on the allowable depletion. The opinion concluded that the depletion of 57,100 afy could not be exceeded in any one year until all the elements of the RPA were completed and/or implemented. This limitation was waived in the event that Reclamation lowered the winter releases from Navajo Reservoir to 300 cubic feet per second (cfs) to provide the extra flexibility in releases described in the hydrology section of the 1991 Opinion. If that condition existed, then the project could maintain an average annual depletion of 57,100 af. The commitment to this operation scenario must be maintained or the conditions of the biological opinion would be violated.

% The Service issued a Final Biological Opinion in June 2000 which supercedes previous Opinions. The
% Service concluded that the project is not likely to jeopardize the continued existence of the Colorado
% pikeminnow or razorback sucker, provided conservation measures, including reoperation of Navajo
% Reservoir to mimic a natural hydrograph according to flow recommendations discussed below, are
% included in the project plan.

1.3 Flow Recommendation Report

At the completion of the seven-year research study in 1998, the SJRBRIP Biology Committee completed a flow recommendation report (Holden 1999). The report spells out the flow recommendations for the endangered fish in the San Juan River below Farmington, New Mexico. The recommendations define the conditions for mimicking a natural hydrograph. Mimicry of a natural hydrograph is defined in the report in terms of magnitude, duration and frequency of flows in the San Juan River. **Tables 1-1** and **1-2** summarize the required conditions.

These recommendations have been accepted by the SJRBRIP Coordination Committee and have been provided to the Service for their use in future Section 7 consultations. It is the position of the SJRBRIP that these flows are necessary to avoid jeopardizing the continued existence of the endangered fish. If the Service chooses to follow these recommendations, then the flow criteria would have to be met to avoid jeopardy.

Table 1-1
Summary of Flow Recommendations for Endangered Fish in the San Juan River %
(as measured at Four Corners gage) %

A.	Category:	Flows > 10,000 cfs during runoff period (March 1 to July 31).
	Duration:	**5 days minimum**, natural variability maintained by meeting the conditions in Table 1-2.
	Frequency:	**20 percent on average**. Minimum frequency for other durations listed in Table 1-2. Maximum period without meeting at least 97 percent of the specified conditions is 10 years.
B.	Category:	Flow > 8,000 cfs during runoff period.
	Duration:	**10 days minimum**, natural variability maintained by meeting the conditions in Table 1-2.
	Frequency:	**33 percent on average**. Minimum frequency for other durations listed in Table 1-2. Maximum period without meeting at least 97 percent of the specified conditions is 6 years.
C.	Category:	Flow > 5,000 cfs during runoff period.
	Duration:	**21 days minimum,** natural variability maintained by meeting the conditions in Table 1-2.
	Frequency:	**50 percent on average**, minimum frequency for other durations listed in Table 1-2. Maximum period without meeting at least 97 percent of the specified conditions is 4 years.
D.	Category:	Flow >2,500 cfs during runoff period.
	Duration:	**10 days** minimum, natural variability maintained by meeting the conditions in Table 1-2.
	Frequency:	**80 percent on average**, minimum frequency for other durations listed in Table 1-2. Maximum period without meeting at least 97 percent of the specified conditions is 2 years.
E.	Category:	Peak timing similar to historical conditions, including variability.
	Timing:	Mean peak with operation to be within 5 days ± of historical period mean.
	Variability:	Standard deviation of date of peak to be 14 to 25 days.
F.	Category:	Target base flow (mean weekly non-spring runoff flow).
	Level:	500 cfs from Farmington to Lake Powell, with 250 cfs minimum from Navajo Dam.
G.	Category:	Flood control releases (incorporated in operating rule).
	Control:	Handle flood control releases as a spike (high magnitude, short duration) and release when flood control rules require, except that the release shall not occur earlier than September 1. If an earlier release is required, extend the duration of the peak of the release hydrograph. A ramp-up and ramp-down of 1,000 cfs per day should be used to a maximum release of 5,000 cfs. If the volume of water to release is less than that required to reach 5,000 cfs, adjust the magnitude of the peak accordingly, maintaining the ramp rates. Multiple releases may be made each year. These spike releases shall be used in place of adjustments to base flow.

Table 1-2 Frequency Distribution Table for Flow/Duration Recommendations				
	Discharge			
	>10,000 cfs	**>8,000 cfs**	**>5,000 cfs**	**>2,500 cfs**
Duration	**Average Frequency**			
1 day	30%	40%	65%	90%
5 days	**20%**	35%	60%	82%
10 days	10%	**33%**	58%	**80%**
15 days	5%	30%	55%	70%
20 days		20%	**50%**	65%
30 days		10%	40%	60%
40 days			30%	50%
50 days			20%	45%
60 days			15%	40%
80 days			5%	25%
Note: Primary criteria shown in bolded, shaded cells.				

Also included in the flow recommendation report are suggested operating conditions for several levels of development in the basin. Applying these rules allows water development to proceed and average annual depletion in the basin to increase above the level set in the 1991 Opinion (642,100 af measured at the United States Geological Survey (USGS) gaging station on the San Juan River at Four Corners, New Mexico). These operating procedures are simply recommendations. Any operating procedure that would allow the flow requirement recommendations for endangered fish to be met would be acceptable. However, before new operating rules could be approved, their ability to produce the required flows would have to be demonstrated. Presently, demonstrating the ability to meet the conditions for the period 1929-1993 has been established as the criteria for assessing the efficiency of any operating rule change or development project.

By applying the operating rules in the flow recommendation report, the depletions, listed in **Table 1-3** as the depletion base, can be made and the flow recommendations met. Several development scenarios were analyzed with these rules in place, representing incrementally greater amounts of depletion. While the actual amount of additional depletion allowed is dependent upon the nature of the depletion, the scenarios analyzed indicated that an additional depletion of at least 122,000 af could be made and the flow recommendations met. The depletions included in these projected development scenarios are included in Table 1-3.

This level of depletion is sufficient to complete the NIIP, but not much more. The San Juan River Basin hydrology model is in a continual state of review and improvement. As the tool improves, and as operating rules become more refined, it is possible that a set of operating rules could be developed that would allow better optimization of the required flow conditions while conserving water for development. If that can be done, then additional project depletions beyond the NIIP and ALP Project could occur.

1.4 Future Regulatory/NEPA Process for the Navajo Unit Outside the ALP Project SEIS

In settlement of a law suit in 1996 over reduced winter test flows, Reclamation agreed to complete an environmental impact statement (EIS) on the new operation of Navajo Dam prior to reducing base releases below 500 cfs. This EIS will include a Section 7 consultation on the operation of Navajo Dam %
to implement the flow recommendations. %

Table 1-3
Summary of Average Annual Depletions[a] for Each Model Scenario with a Peak Release of 5,000 cfs From Navajo Dam (From Flow Recommendation Report, Table 7-3)

	Current[b] (af)	Depletion Base[c] (af)	Db+59,000 (af)	Db+122,000 (af)
NEW MEXICO DEPLETIONS[d]				
NAVAJO LANDS IRRIGATION DEPLETIONS				
Navajo Indian Irrigation Project	135,330	149,403	209,402	272,642
Hogback	9,535	12,100	12,100	12,100
Fruitland	6,147	7,898	7,898	7,898
Cudei	715	900	900	900
Subtotal - Indian Lands	**151,727**	**170,302**	**230,301**	**293,541**
NON-NAVAJO LANDS IRRIGATION DEPLETIONS				
Above Navajo Dam	925	1,189	1,189	1,189
Animas River	24,873	36,725	36,725	36,725
La Plata River	8,276	9,639	9,639	9,639
Upper San Juan	6,680	9,137	9,137	9,137
Hammond Area	7,507	10,268	10,268	10,268
Farmers Mutual Ditch	7,462	9,559	9,559	9,559
Jewett Valley	2,379	3,088	3,088	3,088
Westwater	110	110	110	110
Subtotal - Non-Navajo Lands	**58,212**	**79,715**	**79,715**	**79,715**
Total New Mexico Irrigation Depletions	**209,939**	**250,017**	**310,016**	**373,256**
NON-IRRIGATION DEPLETIONS				
Navajo Reservoir Evaporation	29,139	28,274	27,165	26,962
Utah International	31,388	39,000	39,000	39,000
San Juan Power Plant	16,200	16,200	16,200	16,200
Industrial Diversions near Bloomfield	2,500	2,500	2,500	2,500
Municipal and Industrial Uses	6,945	8,963	8,963	8,963
Scattered Rural Domestic Uses[e]	1,400	1,400	1,400	1,400
Scattered Stockponds and Livestock Uses[e]	2,200	2,200	2,200	2,200
Fish and Wildlife[d]	1,400	1,400	1,400	1,400
Total New Mexico Non-Irrigation Depletions	**91,172**	**99,937**	**98,828**	**98,625**
San Juan Project Exportation	107,514	107,514	107,514	107,514
Unspecified Minor Depletions[e]	1,500	1,500	1,500	1,500
Total New Mexico Depletions (Excluding ALP Project)	**410,125**	**458,968**	**517,859**	**580,896**

Table 1-3 (continued)
Summary of Average Annual Depletions[a] for Each Model Scenario with a Peak Release of 5,000 cfs From Navajo Dam (From Flow Recommendation Report, Table 7-3.)

	Current[b] (af)	Depletion Base[c] (af)	DB+59,000 (af)	DB+122,000 (af)
COLORADO DEPLETIONS				
COLORADO DEPLETIONS - Upstream of Navajo Dam				
Upper San Juan River	9,270	10,858	10,858	10,858
Navajo-Blanco River	6,972	7,865	7,865	7,865
Piedra River	7,178	8,514	8,514	8,514
Pine River	67,658	69,718	69,718	69,718
Subtotal - Upstream of Navajo Dam	**91,078**	**96,955**	**96,955**	**96,955**
COLORADO DEPLETIONS - Downstream of Navajo Dam				
Florida River	27,293	28,602	28,602	28,602
Animas and La Plata Rivers	36,500	39,569	39,569	39,569
Mancos River	15,580	19,913	19,913	19,913
Subtotal	**79,374**	**88,085**	**88,085**	**88,085**
Total Colorado Depletions (Excluding ALP)	**170,452**	**185,039**	**185,039**	**185,039**
Colorado and New Mexico Combined Depletions	580,577	644,008	702,898	765,935
ALP Project[f]	0	55,610	55,610	55,610
Subtotal	**580,577**	**699,617**	**758,508**	**821,545**
Utah Depletions[g]	10,929	10,929	10,929	10,929
Arizona Depletions[e]	12,419	12,419	12,419	12,419
Net New Mexico, Colorado, Utah, Arizona Depletions	**603,925**	**722,965**	**781,856**	**844,893**
New Mexico Off-Stream Depletions				
Chaco River[e]	4,608	4,608	4,608	4,608
Whiskey Creek[e]	649	649	649	649
GRAND TOTAL	**609,182**	**728,222**	**787,113**	**850,150**
McElmo Basin Imports	(19,517)	(15,176)	(15,176)	(15,176)
NET TOTAL DEPLETIONS	**589,665**	**713,046**	**771,937**	**834,974**

[a] Depletions shown are those that directly affect flow in the San Juan River. Total depletions associated with some off-stream projects may be greater than the values shown.
[b] Historic Tribal water, other than those for the Navajo Nation projects listed, are included in the non-Navajo depletion categories.
[c] The "Depletion Base" condition is based on depletion levels used in recent Section 7 Consultations for the ALP Project and NIIP with certain "corrections" made by the states of Colorado and New Mexico and adjustments made to reflect natural flow study assumptions. These corrections and adjustments have not been agreed to by the participants of the SJRBRIP nor approved by the Service. Therefore, this "depletion base" should not be construed as the "Environmental Baseline" for purposes of Section 7 Consultation.
[d] New Mexico provided the acreage base upon which irrigation depletions were computed but has not agreed to the method of computing consumptive use or the resulting depletion values.
[e] Indicates off-stream depletion accounted for in calculated natural gains.
[f] Actual planned average depletion is 57,100 af. Depletion shown is from Reclamation's daily model output used in RiverWare.
[g] 1,705 af San Juan River depletion, 9,224 af off-stream depletion - Utah total = 10,929 af.

2.0 ENVIRONMENTAL SETTING AND EXISTING ENVIRONMENT

There are three distinctly different areas of environmental impacts associated with the changed operating conditions at Navajo Dam: the reservoir to the high water mark, the San Juan River from Navajo Dam to the confluence with the Animas River, and the San Juan River from the Animas River confluence to the confluence with Lake Powell.

2.1 Navajo Reservoir to High Water Mark

Navajo Dam was constructed between 1958 and 1963 as a multi-use facility. The reservoir extends 35 miles upstream and captures drainage from 3,190 square miles, holding about 1,700,000 af of water. Besides regulating river flow, it stores water for NIIP, the Hammond Irrigation Project and various municipal and industrial (M&I) uses. In addition, the storage of water for historic downstream uses allows upstream diversions to be made for the San Juan-Chama Project (SJCP). In addition to flood control and the provision of irrigation and municipal water supplies, the reservoir was planned to include recreation.

At the spillway elevation (6,085 feet), the reservoir has a surface area of 15,610 acres with 150 miles of shoreline. The single outlet in the dam is 150 feet below the spillway elevation. The normal operating range for the reservoir is from elevation 6,085 to 5,990 feet. The inactive pool below elevation 5,990 feet contains about 662,000 af of water with a surface area of about 7,400 acres. This large inactive pool supports a variety of water sports and sport fishing. There are public campgrounds and marinas in New Mexico and Colorado associated with the reservoir.

2.1.1 Navajo Reservoir Limnology

Much of Navajo Reservoir is 100 to 330 feet in depth and its shoreline is typically steep with sandstone boulders and bluffs. Submerged vegetation, trees, and woody debris are sparse and generally limited to the upper end of several of the reservoir's arms. The reservoir's arms that are fed by perennial rivers are the Pine, Piedra, and the San Juan Rivers. Large intermittent tributaries entering the reservoir occur in Frances, La Jara, and Bancos Canyons**.** The majority of the reservoir's water enters from the perennial tributaries, but the intermittent arroyos can discharge large amounts of water during storm events. Reservoir inflow is turbid during the spring runoff and probably contributes much of the reservoir's organic matter at this time. Summer storm events may also discharge large amounts of sediment and organic materials to the reservoir from the intermittent tributaries. The remainder of the year the reservoir's inflow is low in suspended solids (Ahlm 1992). Seasonal fluctuation in the reservoir's surface elevation occurs in response to variations in annual rainfall, dam operation for flood control, and water releases to meet downstream agricultural and fisheries needs.

Limnology information for the Colorado portion of Navajo Reservoir includes temperature and dissolved oxygen profile data collected in 1981-1982 by the Colorado Division of Wildlife (CDOW) in the Piedra arm and the San Juan arm, plus a few surface measurements of electrical conductivity, alkalinity, pH, and total hardness for these same stations. In the New Mexico portion of the reservoir, temperature and dissolved oxygen profile data exist for four stations during eight months in 1990 and 1991. This study (Ahlm 1992) also provided four months (February, May, June, and August) of water quality data (nutrients, hardness, alkalinity, conductivity, H, TDS, and turbidity) for the surface, midwater, and bottom of these same four stations. More recently, temperature profile data were recorded near the dam at six-hour intervals from March 30, 1998 through February 17, 1999. **Figures A-1 through A-8** in Appendix A present a portion of the 1990-1991 data as seasonal profiles of temperature and dissolved oxygen for four stations (Ahlm 1992). A comparison of the 1998-1999 temperature data recorded near the dam with these 1990-1991 data for the "Near Dam" station showed a similar temperature distribution and range.

Surface temperatures in the reservoir range from 4.3°C to 23.7°C from winter to summer, respectively. During winter, the reservoir is approximately 4.5°C from top to bottom. From June through September the reservoir is strongly thermally stratified with the thermocline (zone of rapid temperature change) beginning at 11 to 12 meters below the surface. At this time the top 10 meters of water depth is typically 18°C to 23°C. From 15 to 25 meters in depth, summer temperatures are in the range of 10°C to 15°C, while below 30 meters the temperature is typically 5°C to 8°C.

Dissolved oxygen levels during the winter are relatively similar top to bottom and were above 8 mg/L for the three stations in the reservoir arms. Station 4 near the dam had dissolved oxygen concentrations of 7 mg/L at the surface with a gradual decrease to 4.5 mg/L with increasing depth during February (see Figure A-1 in Appendix A). Above the thermocline, the top 10 meters of water are mixed by wind and waves and retain dissolved oxygen levels of 6 to 8 mg/L through the summer. Similar dissolved oxygen levels are maintained in most of the waters below 30 meters where cold temperatures and minimal light penetration restrict biological activity. However, within the thermocline, dissolved oxygen levels are gradually decreased to 3 mg/L as the summer progresses. This minimum dissolved oxygen level occurred at a depth of 15 meters during 1990-1991.

Nutrient levels in the reservoir are sufficiently low to classify it as oligotrophic (Ahlm 1992). The reservoir waters are moderately hard with relatively low conductivity (239 – 287 micromhos per cm).

2.1.2 Navajo Reservoir Fisheries

Fisheries information for the Colorado portion of Navajo Reservoir consists of electrofishing and gill net data collected in 1981-1982 by Colorado Division of Wildlife in the Piedra arm and the San Juan arm. The 1990-1991 studies by New Mexico Department of Game and Fish (NMDGF) (Ahlm 1992) sampled zooplankton as well as fisheries. The fish sampling for this study was conducted using electrofishing gear, hook and line for kokanee salmon sampling, and angler interviews. Although not reviewed for this report, the NMDGF has several years of annual electrofishing data for Navajo Reservoir. Current information on the relative abundance of Navajo Reservoir fish species was obtained through interviews with Mark Wethington, a local NMDGF fisheries biologist.

The 1990-1991 studies found zooplankton densities in Navajo Reservoir to peak in the month of June (Ahlm 1992). Frances Canyon had the highest zooplankton density of the four stations sampled. Copepods were usually about two to three times more abundant than cladocerans. Crayfish are an important component of the forage base for the reservoir's black bass population (M. Wethington, pers. comm.). Utah Division of Wildlife Resources' fisheries biologist Wayne Gustaveson (pers. comm.) found that juvenile crayfish form a large part of the diet of one-year or older black bass in Lake Powell, and this appears to occur in Navajo Reservoir as well (M. Wethington, pers. comm.). During their first year, young-of-the-year black bass feed primarily on zooplankton (W. Gustaveson, pers. comm.).

The fish species occurring in Navajo Reservoir are listed below in **Table 2-1.** This is from a New Mexico survey. There may be other species in the Colorado portions that are not listed in Table 2-1. The kokanee salmon population of the reservoir has good growth and the fish reach 376 millimeters (mm) (14.8 inches) in size. The rainbow trout population is also maintained by stocking. The primary populations of reproducing sport fish in the reservoir are members of the sunfish family. Although largemouth bass occur in some of the warmer arms of the reservoir, more than 90 percent of the black bass population are smallmouth bass. Navajo Reservoir supports a very good fishery for smallmouth bass, and also has good numbers of white and black crappie (M. Wethington, pers. comm.).

Table 2-1 **Fish Species Presently Occurring in Navajo Reservoir**		
Common Name	**Scientific Name**	**Origin/Status***
Kokanee salmon	*Onchorhynchus nerka*	S
Rainbow trout	*Onchorhynchus mykiss*	S
Brown trout	*Salmo trutta*	R
Northern pike	*Esox lucius*	R
Smallmouth bass	*Micropterus dolomieui*	R
Largemouth bass	*Micropterus salmoides*	S
Green sunfish	*Lepomis cyanellus*	R
Bluegill	*Lepomis macrochirus*	R
White crappie	*Pomoxis annularis*	R
Black crappie	*Pomoxis nigromacrolatus*	R
Channel catfish	*Ictalurus punctatus*	R
Black bullhead	*Ictalurus melas*	R
Carp	*Cyprinus carpio*	R
Red shiner	*Cyprinella lutrensis*	R
Golden shiner	*Notemigonus crysoleucas*	R
Fathead minnow	*Pimephales promelas*	R
Speckled dace	*Rhinichthys oculus*	N, U
Mottled sculpin	*Cottus bairdi*	N, U
White sucker	*Catostomus commersoni*	R
Flannelmouth sucker	*Catostomus latipinnis*	N, U
Bluehead sucker	*Catostomus discobolus*	N, U
Roundtail chub	*Gila robusta*	N, U

*S = Population maintained by stocking
R = Reproducing population in reservoir
U = Population status unknown, generally uncommon or unable to survive in reservoir
N = Native to watershed, probably common pre-impoundment
Source: Ahlm 1992 with an update by Mark Wethington of NMDGF

Smallmouth bass spawn in Navajo Reservoir from the first of May through mid-June (M. Wethington, pers. comm.), probably when water temperatures exceed 15.5° C (Moyle 1976; Lee and Paulsen Undated; and Blommer and Gustaveson 1997). Although the smallmouth bass spawning nests may be located in as little as one meter of water depth, a literature review by Lee and Paulsen (Undated) reported the maximum depth of spawning nests for this species to be almost six meters. This same literature review found that the maximum number of days from the initiation of nest construction to free swimming smallmouth bass fry was 20 days.

Largemouth bass also initiate spawning when the spring water temperatures exceed 15.5°C; however, this species constructs its spawning nest in shallower water than smallmouth bass. Its minimum spawning depth is approximately one meter, and its maximum depth reported is a little less than 4 meters (Lee and Paulsen Undated). In general, largemouth bass spawn in shallower water than smallmouth bass. The number of days from the initiation of nest construction to free swimming largemouth bass fry was 15 days.

Crappie spawning occurs in the spring when water temperatures are about 17°C. The spawning nests are typically found in less than 1 meter of water, but are occasionally built as deep as 6 to 7 meters (Moyle 1976).

A creel census of Navajo Reservoir anglers conducted in 1991 showed that 66 percent of the anglers were locals from San Juan County, New Mexico, and another 21 percent were from Santa Fe or Albuquerque. When asked what fish species they fished for in Navajo Reservoir, 41 percent said kokanee, 32 percent fished for bass, 14 percent for trout, and 7 percent for crappie. (Ahlm 1992).

2.2 San Juan River from Navajo Dam to Confluence with Animas River

The San Juan River flows for 44 miles from Navajo Dam to the confluence with the Animas River. Since completion of Navajo Dam, this reach is heavily regulated. The reduction in peak spring flows has encouraged encroachment into the floodplain. Numerous homes are built adjacent to the active channel and some campgrounds and fishing shacks are actually within the normal high water zone of the river. Through the more populated areas, the river has been channelized and bermed to control flooding and prevent property damage. Many of the old secondary channels have become vegetated or converted to ponds and the area has been fenced for cattle grazing and agricultural use. This encroachment of man and vegetation has reduced the flood capacity of the channel through this reach.

The cold, clear releases from Navajo Dam have allowed the establishment of a blue ribbon tailwater trout fishery. The first six miles below the dam are named the “quality waters”. At the lower end of the quality waters, Gobernador Wash enters the river, bringing large sediment loads during storm events. Between Gobernador and Canyon Largo (about 13 miles), the trout fishery diminishes in quality. Below Canyon Largo, the sediment load is generally too high to support a trout fishery. Below Canyon Largo the native fish community becomes more abundant.

About two thirds of the length of this reach is through irrigated agricultural land. Within this area are interspersed domestic and commercial developments accounting for about three to four miles of river frontage as the river passes through Blanco, Bloomfield and Farmington.

2.3 San Juan River from Animas River to Confluence with Lake Powell

Below the confluence with the Animas River, the San Juan River has retained more of its unregulated nature. Since the Navajo Dam regulates only a little more than one half of the flow at this point and the Animas River is unregulated, the flow still exhibits much its natural variability. Although flood magnitude has been reduced through this reach, floods are still common in the range of 10,000 - 14,000 cfs, so there has been less encroachment into the floodplain.

This full reach (180 miles) has been designated as critical habitat for the endangered Colorado pikeminnow. The reach from the Hogback Diversion to the confluence with Lake Powell has been designated as critical habitat for the razorback sucker.

The river has been characterized into eight distinct geomorphic reaches, seven of which (Reaches 1-7) are below the confluence with the Animas River. The characteristics of these reaches appear in **Table 2-2.**

There are five diversion dams in this reach, two supplying coal-fired power plants and three serving Navajo irrigation projects, and a number of other withdrawals for irrigation and municipal water supplies. The water carries a heavy sediment load in this reach, with the highest concentration occurring during high intensity storm events. The river supports some warm-water sports fishing, primarily for channel catfish, but the usage is not high. Most of the riparian area is influenced by adjacent irrigated agriculture through Reach 6 and parts of Reach 5. Because of the flood potential, very little commercial or residential development has occurred within the floodplain.

Table 2-2
Reach Definitions, Variables Considered,
And Their Mean Values Within Each Reach Used in Defining Geomorphically Different Reaches

	REACH	**1**		**2**		**3**		**4**		**5**		**6**		**7**		**8**
CATEGORY	**RIVER MILE**	**0-16**		**17-67**		**68-105**		**106-130**		**131-154**		**155-180**		**181-213**		**214-224**
HABITAT - m^2/mi																
High Flow	Total Water Surface	152,314	≠[a]≠	97,161	≠	199,049	≠	171,983	≠	206,925	≠	133,983	≠	102,519		150,883
	Low Velocity Types	1,920		2,015		1,481		1,893		1,861	≠	946		1,241		13,642
	Riffles/Chutes	42	≠	27,697		30,139		31,237		43,041	≠	10,816	≠	3,713	≠	13,050
	Sand Type	5,704	≠	363	≠	15,132	≠	279		3,224	≠	760		1,615		337
	Cobble Type	0		43	≠	3,726	≠	120		147	≠	632		364	≠	1,692
	Islands 3 mi average	0		109	≠	84,708	≠	117	≠	266	≠	584		529		534
Interme	Total Water	136	≠	74,415	≠	123,940		119,980		122,787						
	Low Velocity Types	4,646		1,192	≠	2,136		2,256		2,546						
	Riffles/Chutes	3,827	≠	19,013		14,373	≠	252	≠	38,382						
	Sand Type	43,108	≠	1,962	≠	8,932		6,923		3,392						
	Cobble Type	1,011		2,342	≠	7,139		7,785	≠	3,655						
	Islands 3 mi average	200		320	≠	51,940	≠	82,210	≠	188,055						
Low Flow	Total Water Surface	114,291	≠	72,142	≠	113,314	≠	104,522		107,422	≠	92,933	≠	77,043		94,636
	Low Velocity Types	2,239	≠	890	≠	1,897		2,026	≠	4,328	≠	8,929	≠	732	≠	17,921
	Riffles/Chutes	9	≠	16,865		14,683		16,113	≠	26,164		26,641	≠	6,746	≠	30,260
	Sand Type	26,112	≠	1,125	≠	7,195		5,526	≠	2,918	≠	586		1,337		0
	Cobble Type	309	≠	1,522	≠	2,572	≠	403		3,197		2,584		3,185		2,988
	Islands 3 mi average	0		173	≠	44,473	≠	71,249	≠	196,178	≠	21,675	≠	46,921		60,728
RIPARIAN VEGETATION - m^2/mi																
	Cottonwood					6,094	≠	2,847		4,909	≠	10,043				
	Russian Olive					26,643		28,701	≠	46,053	≠	35,119				
	Tamarisk					25,167	≠	31,224		32,536	≠	19,124				
	Willow					6,592		7,393	≠	3,007		4,499				
	Upland Herbaceous					1,811		7,182	≠	15,801	≠	9,569				
	Upland Shrub					7,897	≠	7,056	≠	2,349		2,647				
	Wetland Herbaceous					524		718	≠	8,737		11,509				
CHANNEL - 3 mile average																
	Valley Width - m	102	≠	66	≠	1122	≠	986	≠	2299		2028		1957	≠	574
	Channel Slope - ft/ft	0.00105	≠	0.00178	≠	0.00143	≠	0.00164	≠	0.00193	≠	0.00209		0.00213	≠	0.00160
	Sinuosity	1.00000		1.00001	≠	1.09096	≠	1.12311	≠	1.16862		1.18715		1.15081	≠	1.19527

C-12

Table 2-2 (continued)
Reach Definitions, Variables Considered,
And Their Mean Values Within Each Reach Used in Defining Geomorphically Different Reaches

STREAM CHANNEL CONTACT																
	Bedrock - m/mi					206		182		243		140				
	Eroding Bank - m/mi (Sand/Gravel/Cobble)					713	≠	324		323		316				
	Contains Sand					93.6%	≠	96.4%		86.2%		84.6%				
	Contains Gravel					29.7%	≠	31.1%	≠	7.8%	≠	26.5%				
	Contains Cobble					34.6%		64.0%		62.2%		58.1%				
	Sand Only					86.1%	≠	66.4%		68.7%		41.0%				
	Gravel Only					21.3%	≠	9.3%		6.2%		10.8%				
	Cobble only					15.2%		21.7%		23.2%		25.3%				
CATEGORICAL VARIABLES																
	Adjacent Irrigated Area - %	0.0%		0.0%		23.7%		0.0%		83.3%		100.0%		100.0%		30.0%
	Major Tributary - Ephemeral	0		0		6		3		2		0		2		2
	Major Tributary - Perennial	0		0		2		1		1		3		1		0
	Bridge	0		1		4		1		1		2		2		1
	Diversion	0		0		0		0		1		4		1		1
	Oil Well	0		2		4		0		0		0		0		0
	Pipe Crossing	0		0		1		0		2		1		0		0
	Borrow Pit	0		1		1		0		0		0		0		5
	Pond	0		1		6		2		2		0		0		0
	Road	2		1		6		0		0		0		0		0
	Sewage Treatment	0		0		3		0		3		3		0		0

[a] ≠ = not equal to.
Note: Shaded rows show significant variables.
Source: Bliesner and Lamarra 1995

3.0 FLOW CONDITIONS

3.1 Historical Operation (1962 - 1991)

Navajo Dam began regulating the San Juan River in 1962, although construction was not completed until 1963. The reservoir was filled slowly between 1962 and 1973, the first year it reached full capacity. Most of the projects that required water from the reservoir were not on line during this period, so there was a surplus of water. From initial filling through 1991, the dam was typically operated to minimize fluctuations in downstream flow while maximizing stored water. Based upon forecast inflow, the reservoir level was typically lowered in the late winter and early spring to allow storage of the inflow without large increases in releases. The result was a depression of the peak flow and increase in base flow as shown in **Figure 3-1** for the flows at Archuleta. The effect below the confluence with the Animas River is shown in **Figure 3-2**.

The objective of maintaining more uniform flows from the dam is obvious in both figures, with increased base flow and decreased peak flow.

Although the major projects for which the dam and reservoir were constructed are now taking water, they are not all at capacity. The SJCP began delivering water in 1970 and is now at nearly full capacity, averaging about 110,000 afy. The NIIP began taking water in 1976 and is still only a little more than 50 percent capacity, demanding only about 160,000 afy of the long term average demand at completion of about 337,000 afy. The Jicarilla Apache settlement water right of 25,500 afy is not developed, nor is the Navajo-Gallup Pipeline with a need for approximately 31,9000 afy. The reduction in demand during this %
period has resulted in less drawdown and fluctuation in the reservoir than would have been anticipated under full development.

When analyzing the reservoir level fluctuation for this period, statistics were computed for the 1973-91 period. The years prior to 1973 represented the filling period and are not indicative of the operating criteria employed for normal operation. During this period, the mean end-of-month reservoir water surface elevation was 6,054.7 feet, with an average annual fluctuation of 29.6 feet. The maximum change in one year was 69.2 feet in 1973. The plot of end-of-month water surface elevation appears in **Figure 3-3**.

3.2 Historical Operation (1992 - 1998)

The test flows scheduled for the seven-year research program on the San Juan River began in 1992. The flows were designed to restore a more natural hydrograph, but provided some variation in the shape and magnitude of the release from year-to-year. The resulting hydrograph is shown against the pre-dam and post-dam historic hydrographs for the San Juan River at Archuleta and Bluff in Figures 3-1 and 3-2 respectively. The restoration of a natural like hydrograph is obvious, although the peak is narrower than the historic condition. This is due to the depletions that have occurred in the basin as a result of the reservoir. The total volume of water available for release has been reduced and that reduction has resulted in a narrowed runoff hydrograph.

The demand on Navajo Reservoir during this period is still about 240,000 afy below the planned demand. This reduction in demand continues to allow less drawdown in the reservoir and less fluctuation in reservoir content than will be expected at full development.

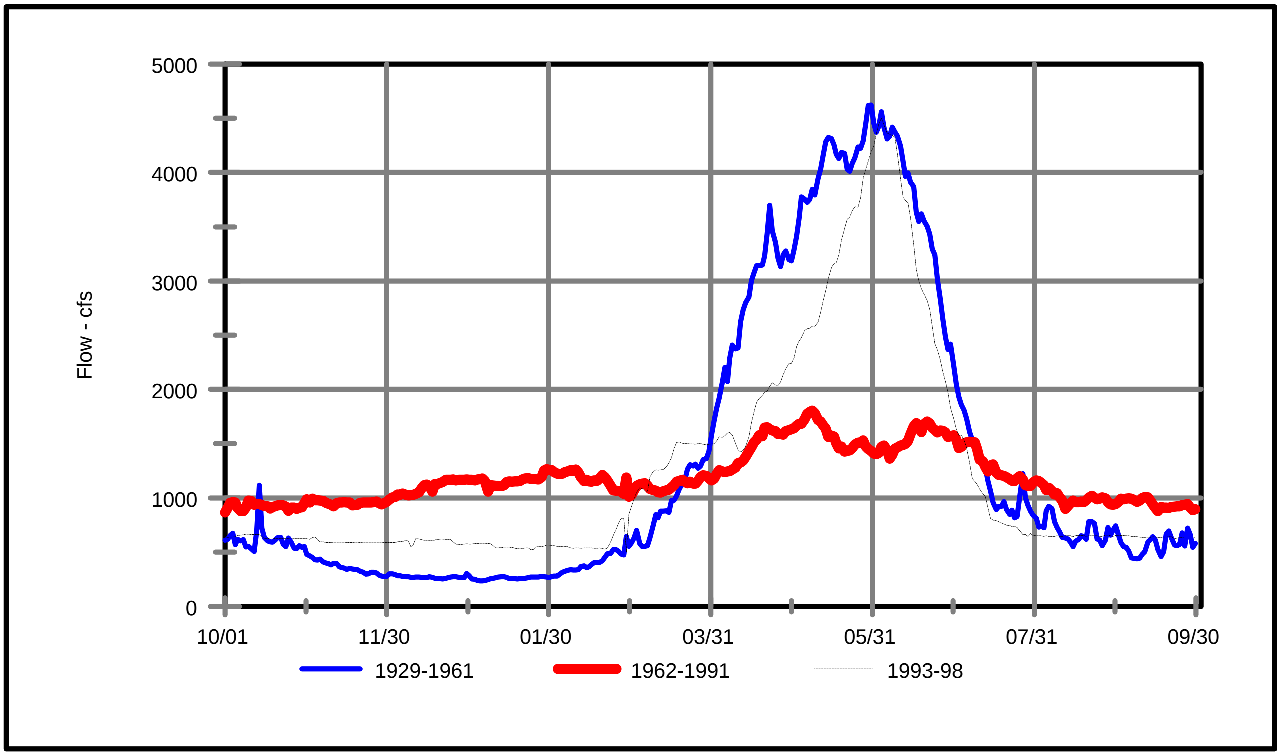

Figure 3-1 Comparison of 1929-61, 1962-91 and 1993-98 hydrographs for the San Juan River at Archuleta

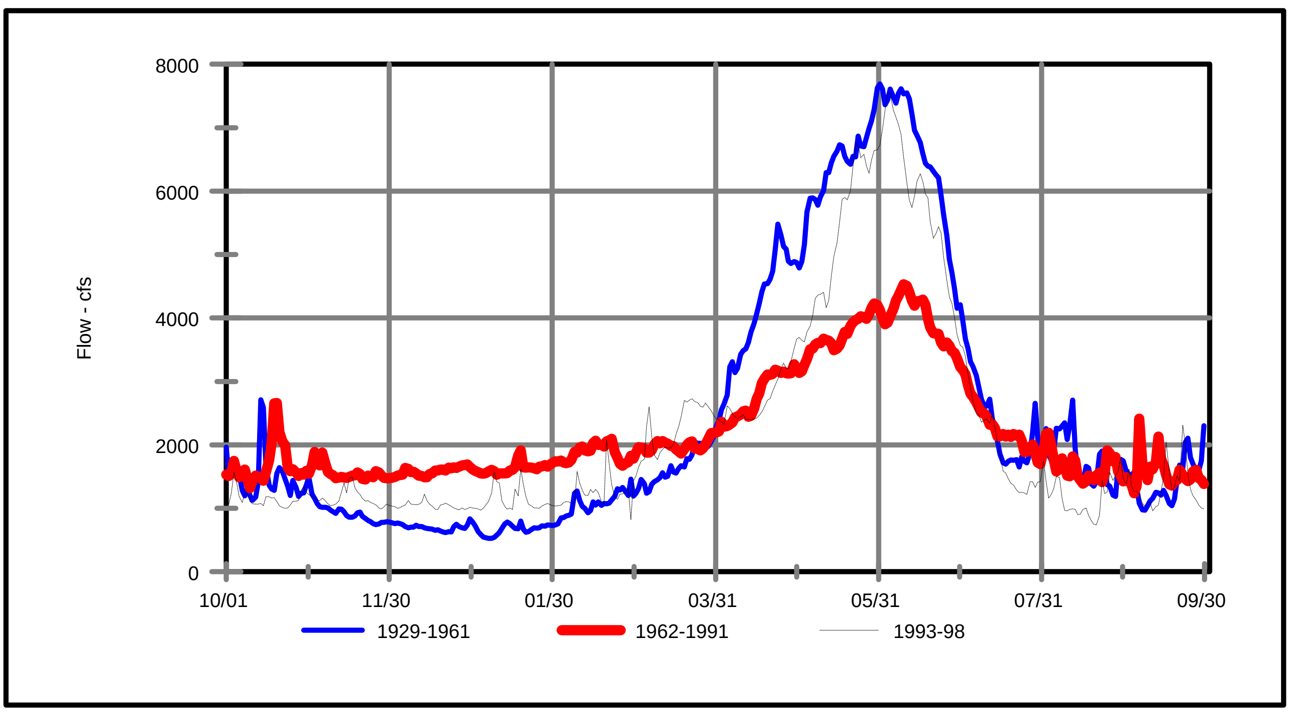

Figure 3-2 Comparison of 1929-61, 1962-91, and 1993-98 hydrographs for the San Juan River near Bluff

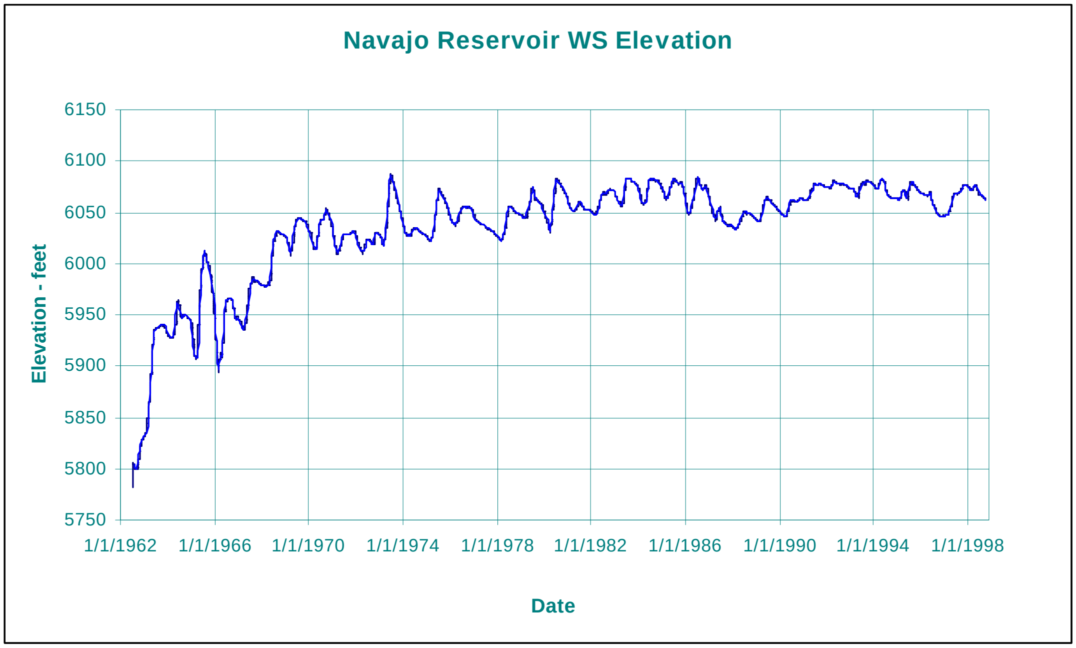

Figure 3-3 Navajo Reservoir Water Surface Elevations, Historical Conditions

During the research period, the reservoir water surface elevation averaged 6,069.6 feet with an average annual variation of 17.5 ft and a maximum annual change of 28.5 feet. The higher water surface elevation and reduction in annual variation is partly due to this being a slightly wetter-than-average period.

3.3 Simulated Conditions as Designed with Planned Level of Development

Two potential baseline conditions exist for comparison to planned operation. The original operation included an average annual diversion requirement for NIIP of 508,000 Af. The second condition is that described in the 1976 EIS for the NIIP. An analysis of the comparative impacts will require modeling these conditions, which is beyond the scope of the connected action analysis and will be deferred until the completion of the EIS for Navajo Dam operation. Some narrative is included in each section based on existing data.

3.3.1 Results of Simulated Operation with Demands as Planned at the Time of Construction (1962)

The diversion requirement of 508,000 Af envisioned for NIIP would result in significant reservoir drawdown and some shortages that would be shared among contractors without scheduled releases for endangered species. A full model analysis is required to determine these impacts.

3.3.2 Results with Full Development Under Conditions Presented in NIIP 1976 EIS

The 1976 EIS for the NIIP characterized the maximum fluctuation in water surface elevation to be 95 feet. This fluctuation would not occur in any single year, but would result from a multiple-year drought. The average annual variation was expected to be about 30 feet. The maximum annual change could be as much as 54 feet. In addition, the 95 feet was exceeded during 5 years using the historical hydrology records from 1906 to 1963.

The impacts to downstream flows in the river cannot be determined without model runs, as they were not reported in the EIS.

3.3.3 Selected Conditions for Baseline Analyses

Since Navajo Dam operation was discussed in the 1976 NIIP EIS, this is the most likely baseline condition. The project described at the time is closer to the constructed condition and is most representative of the conditions that would have been expected to occur. Therefore, the reservoir elevation and downstream flows for this operation will form the basis for determining impacts of modified operation to meet flow recommendations. Since the modeling has not been completed for this scenario, no analysis is possible.

3.4 Reservoir Operating Rules Being Considered

The SJRBRIP flow recommendation report (Holden 1999) specifies the flow conditions necessary to meet the requirements of the endangered fish in the San Juan River. Also included in the report is a set of Navajo Reservoir operating rules that would allow the flow recommendations to be met under some level of future development. It is acknowledged in the report that other operating rules could be identified to meet the flow recommendations. As long as the flow recommendations are met, the rules would be acceptable. Listed below is a description of the operating rules in the flow recommendation report and an introduction of other options.

3.4.1 Flow Recommendation Operating Rules - 5,000 cfs Peak

- ❑ Minimum peak release consists of 1 week ramp-up to 5,000 cfs, 1 week at 5,000 cfs, and 1 week ramp-down. Daily flow rates for ramping are given in **Table 3-1**. Volume is 114,000 af above average base release of 600 cfs.

- ❑ Primary peak release hydrograph consists of 4 week ramp up to 5,000 cfs, 3 weeks at 5,000 cfs, and 2 weeks ramp-down. Ramp rates are given in Table 3-1. Volume is 344,000 af above the average base release of 600 cfs.

- ❑ The peak release is to be centered on June 4 of each year.

- ❑ Use the decision tree shown in **Figure 3-4** to determine the magnitude of release. Available water on the chart is defined as: "*predicted inflow less base release plus available storage*," where available storage is reduced from full storage by the amount of carry over storage necessary to prevent shortages in future years. "*Release last 3 years > 344,000 af*," means that a release of at least 344,000 af occurred at least once out of the last 3 years. **Table 3-2** lists the model calibrated values for carryover storage to be used in this calculation for a development range. When new development is proposed, the model should be operated to verify the value to be used.

- ❑ In years when the spill is predicted to be greater than 344,000 af, adjust the hydrograph by first adding a nose of 2,000 cfs and extending it to as early as March 1. Increase nose by 500 cfs and increment calculation of duration until time extension is March 1, if necessary. Ramp-up on beginning of nose from base flow cannot exceed 1,000 cfs per day.

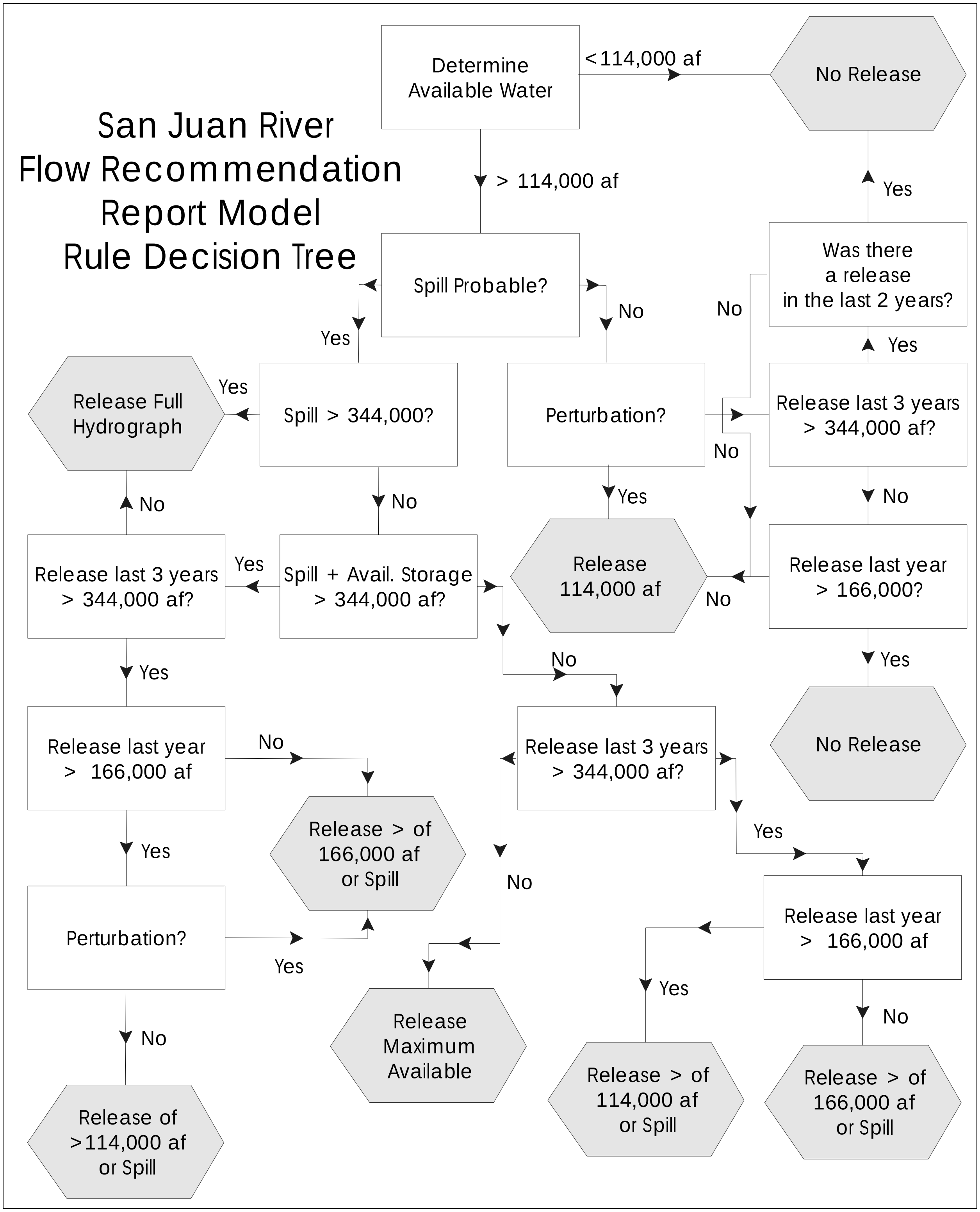

Figure 3-4 **Flow Chart of Navajo Dam Operating Rules for 5,000 cfs Peak Release**

Table 3-1
Recommended Daily Ramp Rates for 1-Week, 2-Week, 3-Week, and 4-Week Ramps for 5,000 cfs Peak Release

Day	Flow Rate			
	1-Week	2-Week	3-Week	4-Week
1	1,000	1,000	1,000	1,000
2	1,500	1,000	1,000	1,000
3	2,000	1,500	1,000	1,000
4	2,500	1,500	1,000	1,000
5	3,000	2,000	1,500	1,000
6	3,500	2,000	1,500	1,000
7	4,000	2,500	1,500	1,000
8	5,000	2,500	2,000	2,000
9		3,000	2,000	2,000
10		3,000	2,000	2,000
11		3,500	2,000	2,000
12		4,000	3,000	2,000
13		4,000	3,000	2,000
14		4,500	3,000	2,000
15		5,000	3,000	3,000
16			4,000	3,000
17			4,000	3,000
18			4,000	3,000
19			4,000	3,000
20			4,000	3,000
21			4,000	3,000
22			5,000	4,000
23				4,000
24				4,000
25				4,000
26				4,000
27				4,000
28				4,000
29				5,000

Table 3-2 Minimum Carryover Storage for Modeled Levels of Development for Use in Determination of Available Water per Figure 3-3						
Development Level	**Current**	**Depletion Base**	**Dep Base +59,000**	**Dep Base +122,000**	**Dep Base +210,000**	**Dep Base +280,000**
Carryover Storage for 5,000 cfs (af)	900,000	1,000,000	1,288,200	1,453,200	1,700,000	1,700,000

❑ In years when the release will be greater than 114,000 af, but less that 344,000 af, use the following adjustment rules in this order of selection:

1. Decrease time of descending limb by as much as 1 week to achieve necessary reduction.

2. Decrease time of ascending limb by as much as 3 weeks to achieve necessary reduction.

3. Reduce duration of peak by as much as 2 weeks.

4. Ramping rates are shown in Table 3-1. Rates shown are ideal rates and may be adjusted within reasonable limits to accommodate dam operating procedures and flood control requirements. Changes should not exceed 1,000 cfs per day.

❑ Target base flow (average weekly) following spring peak is 500 cfs at Farmington, Shiprock, Four Corners, and Bluff gages, measured as the average of any two of these gages. Minimum release is 250 cfs. The target flow should be maintained between 500 and 600 cfs, attempting to maintain flow closer to 500 cfs.

❑ Handle flood control releases as a spike (high magnitude, short duration) and release when flood control rules require, except the release shall not occur earlier than September 1. If an earlier release is required, extend the peak duration of the release hydrograph. A ramp up and ramp down of 1,000 cfs per day should be used to a maximum release of 5,000 cfs. If the released volume is less than that required to reach 5,000 cfs, adjust the magnitude of the peak accordingly, maintaining the ramp rates. Multiple releases may be made each year. These spike releases shall be used in place of adjustments to base flow.

❑ In no case shall the reservoir be allowed to fall below the elevation that allows full diversion of water to the NIIP.

3.4.2 Flow Recommendation Operating Rules - 6,000 cfs Peak

By adjusting the peak release from 5,000 to 6,000 cfs, it is possible to maintain flow recommendations at higher levels of development. The rules are the same as those listed in 3.4.1, but the volumes in each step are replaced by those that correspond to a 6,000 cfs release. **Table 3-3** lists the comparative volumes for the 5,000 and 6,000 cfs peak releases, respectively. As shown in **Table 3-4**, the ramping rates would also change. The minimum carryover storage is the same as those in Table 3-2, except the storage required for the depletion base plus 59,000 af is 1,125,000 af.

Table 3-3 Comparison of Release Volumes at 5,000 and 6,000 cfs Peak Release	
5,000 cfs Release Volume (af)	**6,000 cfs Release Volume (af)**
114,000	134,000
166,000	198,000
344,000	393,000

Table 3-4
Recommended Daily Ramp Rates for 1-week, 2-week, 3-week, and 4-week Ramps for 6,000 cfs Peak Release

Day	Flow Rate			
	1-Week	**2-Week**	**3-Week**	**4-Week**
1	1,000	1,000	1,000	1,000
2	1,500	1,000	1,000	1,000
3	2,000	1,500	1,000	1,000
4	2,500	1,500	1,000	1,000
5	3,000	2,000	1,500	1,000
6	4,000	2,500	1,500	1,000
7	5,000	2,500	1,500	1,000
8	6,000	3,000	2,000	2,000
9		3,000	2,000	2,000
10		3,500	2,000	2,000
11		4,000	2,000	2,000
12		4,000	3,000	2,000
13		4,500	3,000	2,000
14		5,000	3,000	2,000
15		6,000	4,000	3,000
16			4,000	3,000
17			4,000	3,000
18			4,000	3,000
19			4,000	3,000
20			4,000	3,000
21			5,000	3,000
22			6,000	4,000
23				4,000
24				4,000
25				4,000
26				4,000
27				4,000
28				5,000
29				6,000

The advantage of this option is the possibility of additional depletions from the basin while meeting flow conditions necessary for the endangered fish. The downside is that a 6,000 cfs release from Navajo Dam is greater than historically has been released. There are concerns that the channel capacity between Navajo Dam and Farmington would be exceeded, resulting in property damage. While the original design capacity of the outlet works (main plus auxiliary) is 6,700 cfs, post-construction tests set a safe operating limit of 4,900 to 5,000 cfs. Some remedial work was completed to reduce damage to the stilling basin, but all concerns have not been addressed to allow the outlet works to release above 5,000 cfs for regular operation. Further investigation and possibly testing would be required to verify the outlet capacity and determine modifications necessary to increase the capacity above 5,000 cfs. Additional design and field work would be required to determine channel capacity as well. Testing of other operating rules may negate the need to increase releases to 6,000 cfs if these other rules would suggest more developable water while meeting flow recommendations.

3.4.3 Operating Rules Optimized for the Flow Recommendation

The operating rules presented in the flow recommendation report were developed during the process of defining the flow recommendations and were not optimized with the flow recommendations in mind. They are designed to prioritize making relatively frequent releases, not necessarily matched to the expected hydrograph. Correlation to the flow requirement and predicted inflow could improve the ability to meet the flow recommendations.

3.4.4 Operating Rules Adjusted to Avoid Adverse Impacts

If, when examining impacts, the rules adversely affect another resource, it may be possible to adjust the timing of releases to avoid the effect. When these potential impacts are identified, modeling reservoir operation could assist in identifying rules to avoid or reduce the effects of them.

In the process of completing the FSEIS for the ALP Project, additional rules have been developed. Some adjustments were made to the decision tree shown in Figure 3-4 to improve meeting flow recommendations at higher levels of depletion. The revised decision tree is shown in **Figure 3-5**. In addition, two rules were added to meet flow recommendations during low flow periods.

- If the total May plus June flows at the Four Corners Gage did not exceed 650,000 af in any of the past six years, then a maximum release (344,000 af) would be made from Navajo Reservoir, provided water was available to make the release.

- If the total May plus June flows at the Four Corners gage is less than 200,000 af in each of the past three years, then the base release prior to any peak release is increased to 550 cfs in May of the current year.

These two rule changes have been included in the modeling for the ALP Project and are the current recommended operating rules for Navajo Dam. They may be modified in the future as more information is received, the model is refined, or the flow recommendations are modified through adaptive management.

3.4.5 Maintain Historic Operating Rules

The No Action Alternative would be to continue the operation as in the past, with the objective of maintaining minimum variability in downstream flow while maximizing available storage.

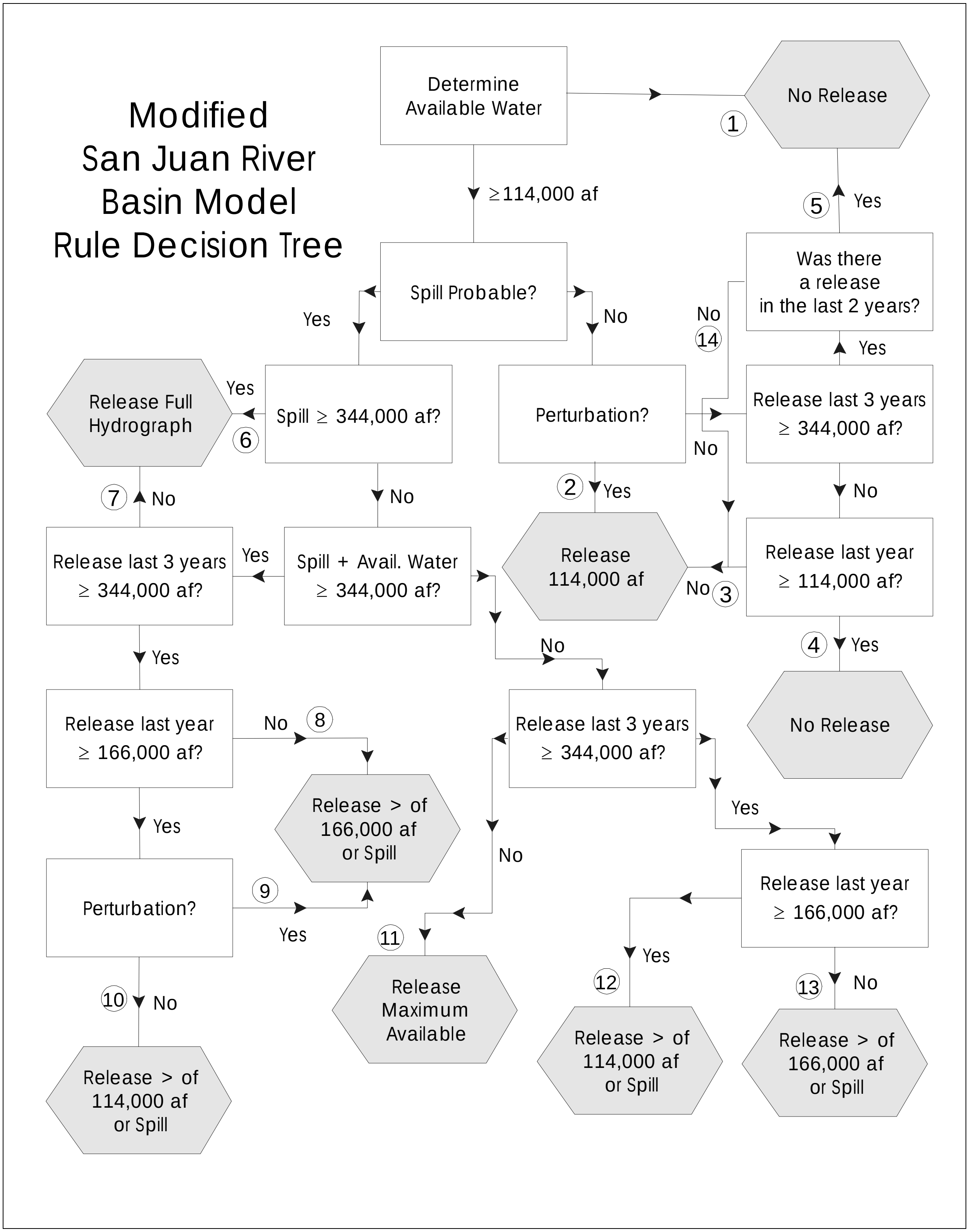

Figure 3-5 Modified Flow Chart of Navajo Dam Operating Rules for 5,000 cfs Peak Release

3.4.6 Selected Conditions for Analysis of Connected Action

Since the analysis of the impact of this connected action must rely on existing data, the only operating scenarios possible are the currently recommended operating rules with 5,000 cfs peak release and the no-action alternative. Even the no-action alternative cannot be completely analyzed without some additional analysis to project those operating conditions over time.

4.0 STATUS OF CURRENTLY AVAILABLE DATA AND POTENTIAL IMPACTS OF VARIOUS OPERATIONAL OPTIONS

4.1 Air Quality and Noise

The project will not involve construction activities in the vicinity of Navajo Reservoir, nor will the change in the reservoir's operations alter the frequency or magnitude of recreational use on the reservoir. There is no impact to air quality and noise from this change in operating criteria from baseline conditions.

4.2 Agriculture (including Downstream Water Rights/Users)

Downstream impacts may include increased frequency of flooding and bank erosion of pasture and agricultural land along the river during the more frequent high flows. Without a revised operation to meet flow recommendations, it is likely that further development of water projects will be limited in the basin as evidenced by the 1991 NIIP Section 7 consultation which did not allow for any new depletion until the flow requirements were determined. This would mean that the NIIP could not be completed, violating the conditions of legislation under which the Navajo Nation agreed to the depletion of 110,000 af of water annually for the SJCP. Therefore, agriculture in both the Rio Grande and San Juan Basins could be affected.

Although data for these impacts have not all been gathered, records exist on agricultural uses and water rights to adequately discuss impacts.

4.3 Hydrology

4.3.1 Navajo Reservoir Water Content

The operation of Navajo Reservoir is impacted by project operation in that additional water must be released from Navajo Dam to offset downstream impacts of the project in terms of meeting the flow requirements of the endangered fish. With project operation the average reservoir content drops by 20,500 af from 1,347,500 af (79 percent full) to 1,327,000 af (78 percent full). The minimum reservoir content drops from 645,700 af to 637,500 af, or about 12,000 af above the minimum allowable content.

Navajo Reservoir water content was modeled for the following two sets of reservoir operation.

Baseline Operation:	Existing conditions plus all currently approved water development projects including full NIIP; this does not include the ALP Project.
Standard Operation:	The same as Baseline Operation, but includes the ALP Project.

Figure 4-1 shows the frequency distribution of Navajo Reservoir content over the modeling period (1929 through 1993) for these two operating conditions. The end-of-month content for baseline and Preferred Alternative operation are shown in **Figures 4-2 and 4-3,** respectively. These changes in reservoir levels through project operation are within the significance criteria established for evaluating impacts to water resources (see Chapter 3, Section 3.2 of the ALP Project FSEIS for significance criteria) and are therefore not significant.

For comparison to historic conditions, the reservoir content data from 1973 through 1993 was used. Prior to 1973, the reservoir had not filled and operations had not stabilized, so the data are not valid for comparison purposes. Since the reservoir demands were low during this period compared to design demands, the historic record does not necessarily provide the correct baseline against which to assess impacts of changes in operation to mimic a natural hydrograph. However, a comparison to historical conditions is instructive in understanding the changes. For this period, the historical average reservoir content was 1,326,000 af compared to 1,414,400 af for the future condition without the ALP Project and 1,397,600 af for the future condition with the ALP Project. While the average content is slightly higher when operated to mimic a natural hydrograph for the period of comparison, the minimum contents are actually slightly lower. For the future with ALP Project condition, the minimum content for the period was predicted to be about 868,000 af, compared to 860,000 af for the future without the project and 888,000 for the historical record. These minimum contents correspond to elevations of 6,015, 6,014 and 6,017 feet, respectively, for the three conditions. This represents a lowering of up to 2 feet in the extreme year, even though the average elevation is about 5 feet higher. Further, the average annual fluctuation in reservoir content is less with operation to mimic a natural hydrograph than under historic conditions. The average change with operation to mimic a natural hydrograph with implementation of the ALP Project is only 18.5 feet per year, while the average for the historical record for 1973-1993 is almost 28 feet. The nature of the change is different, however, with the historical levels rising rapidly during runoff and the biggest decline occurring during the late winter. With operation to mimic a natural hydrograph, the water levels typically decline during runoff and rise during the winter as the reservoir refills.

Data are not available to evaluate the expected water surface elevation for the full model period for the No Action Alternative (no change in reservoir operation from that discussed in the 1976 EIS for NIIP). Modeling of these operating rules will be required to assess this change. Based on the change from historic conditions, the impact will likely be small and will be positive for some resources and negative for others. These impacts will be assessed as part of the Navajo Unit Operation EIS.

4.3.2 Navajo Dam Releases

For any of the project alternatives, the hydrology of the San Juan River below Navajo Dam will be significantly altered from the conditions that have existed since the completion of Navajo Dam. The flow regimes will be altered to more natural conditions downstream of the dam for the purpose of meeting flow recommendations for endangered fish in the San Juan River. All project alternatives are able to meet the San Juan River instream flow requirements as specified in the flow recommendation report (Holden 1999).

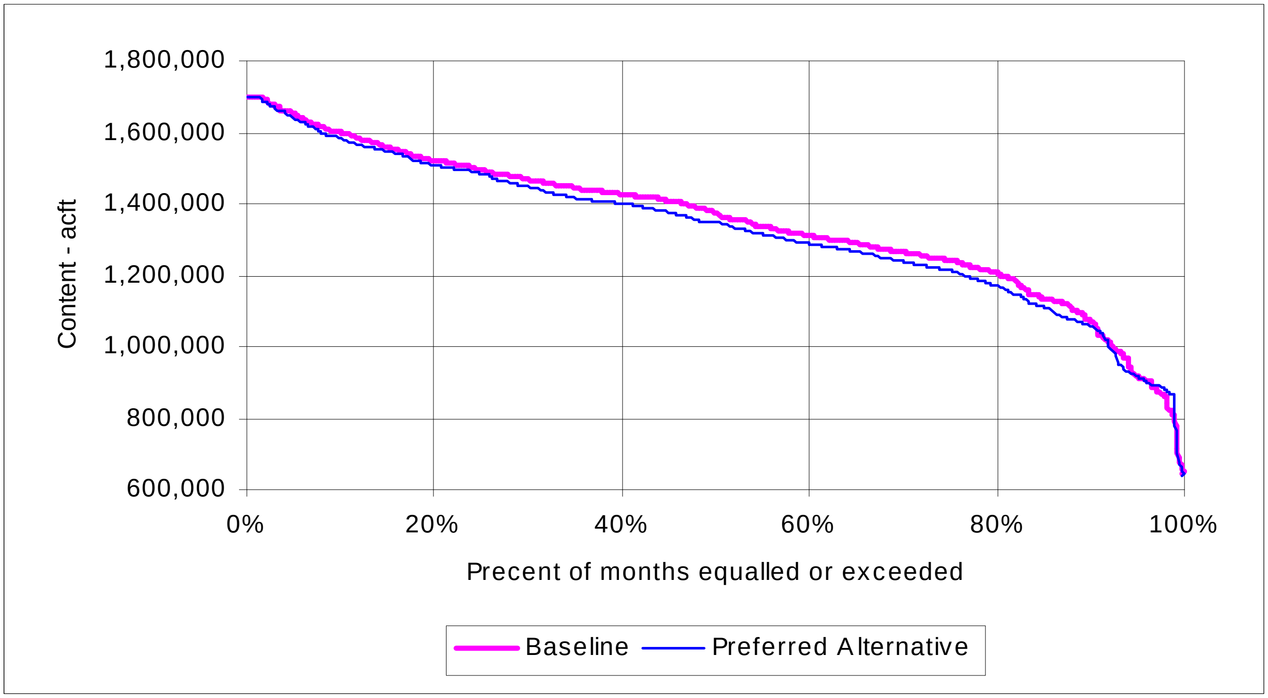

Figure 4-1 **Frequency Distribution of Navajo Reservoir Content for the Period 1929-1993 under Baseline, Standard Project Operation and Operation for Mitigation of Impacts to Indian Trust Water Supply**

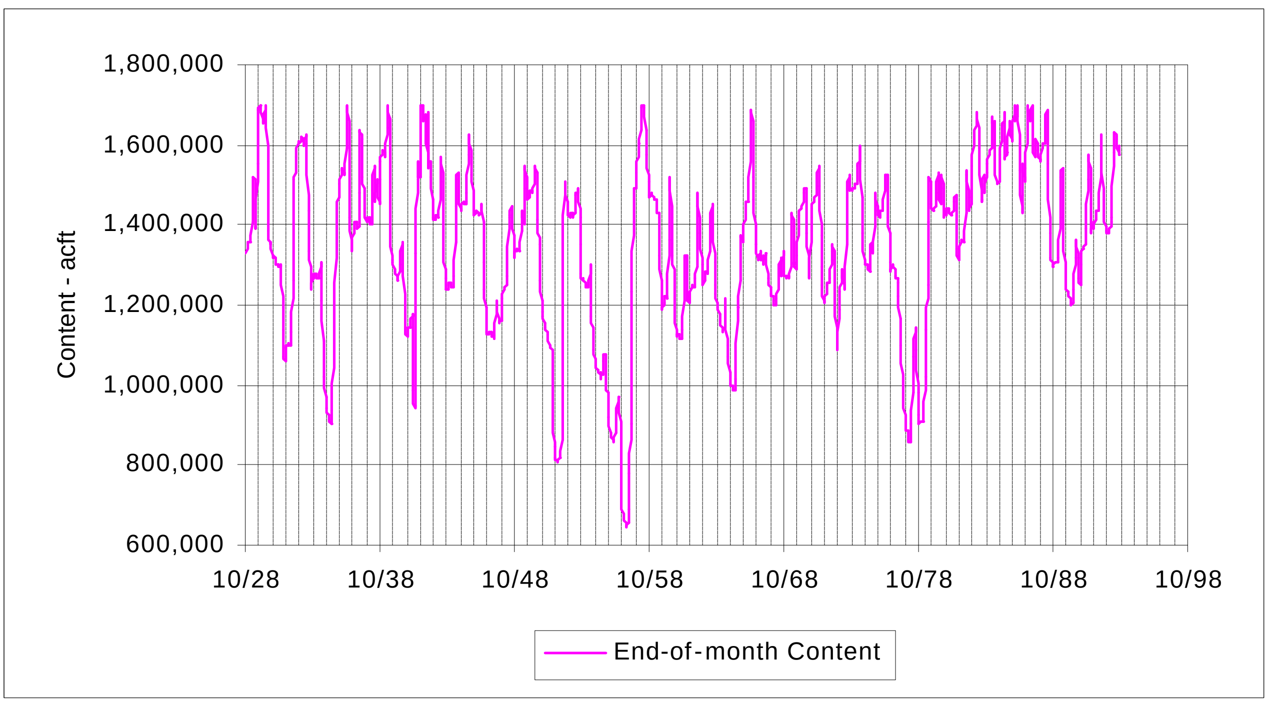

Figure 4-2 **Navajo Reservoir End-of-month Content for the Period 1929-1993 under Baseline Operating Conditions**

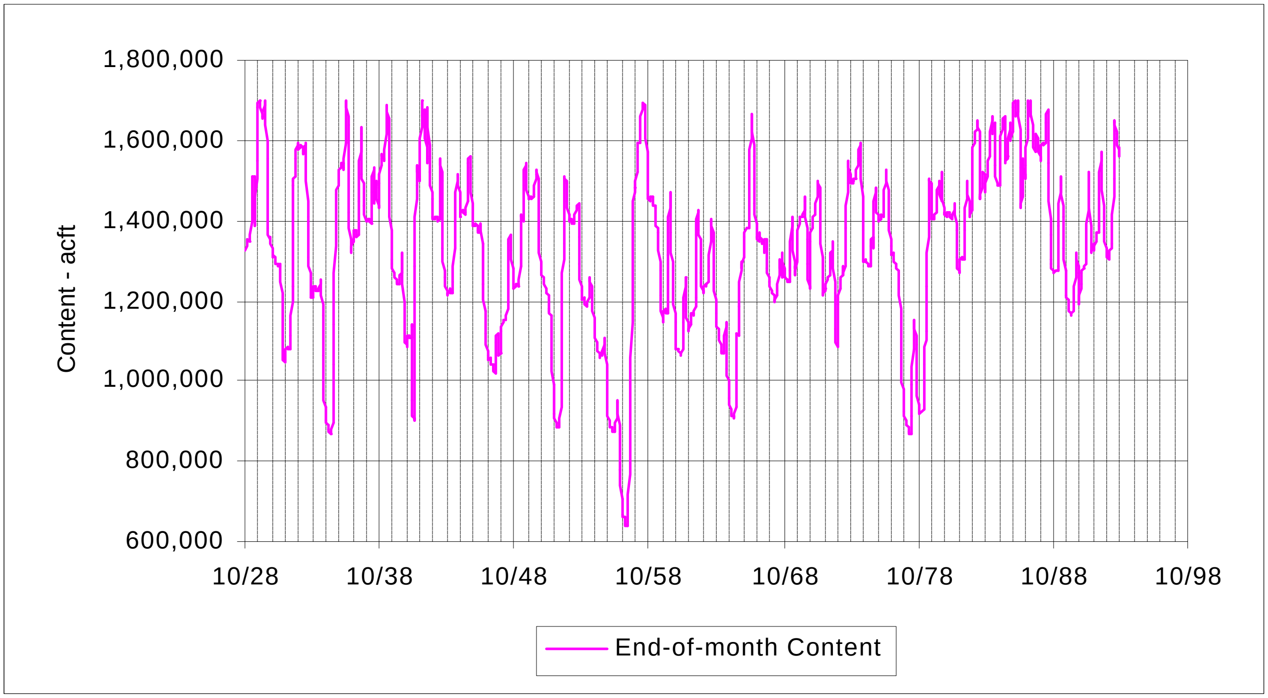

Figure 4-3 **Navajo Reservoir End-of-month Content for the Period 1929-1993 under Standard Project Operating Conditions**

The greatest change, from historical condition due to operation to mimic a natural hydrograph, occurs in the San Juan River from Navajo Dam to Farmington (see Figure 3-2). While the high and low flows anticipated in this reach are within the historic range, the extremes in the range will occur more frequently than during the 1962-1991 post-dam period to more closely match a natural flow pattern. The increased frequency of high flows will increase bank erosion and maintain a more natural stream channel. During low-flow conditions the ability of diversion structures to obtain the necessary water from the river may be affected.

Downstream of Farmington, New Mexico, the change is less significant. The impacts have been studied for eight years and were used to develop the SJRBRIP flow recommendations. No significant adverse effects have been noted, but not all data have been analyzed for all impacts. Studies have been conducted on these effects, although some additional data collection may be necessary to fully study the impacts. The impacts will be fully addressed as part of the Navajo Unit Operation EIS.

4.4 Aquatic Ecology and Fisheries

4.4.1 Navajo Reservoir Limnology

The effect of operation to mimic a natural hydrograph on the water level of Navajo Reservoir is minor and there is little difference between the water surface elevation of the reservoir under conditions of Baseline Operation (without the ALP Project) and Standard Operation (with the ALP Project) (see Figures 4-1 through 4-4). There is also little difference in average conditions compared to the historical record. There are changes in timing of reservoir fluctuation and the impact in this change must be addressed. While it appears unlikely that the small change in water surface elevation will have a significant effect on limnology, it has not been fully examined. This concern will be evaluated in greater detail in the Navajo Unit Operation EIS.

4.4.2 Navajo Reservoir Flatwater Fisheries

Generally, the water surface elevation of Navajo Reservoir increases in the spring, declines during the summer, and has short-term increases and decreases during this time in response to the anticipated magnitude of spring runoff, storm events, and the requirement to meet downstream water needs for stream fisheries and agriculture. The black bass and crappie populations of the reservoir typically spawn in May through mid-June and can be adversely impacted by reservoir fluctuations during this period. The reproductive success and year-class strength of a reservoir's bass and crappie fisheries are affected by several environmental factors that occur after spawning. These factors are: water level fluctuation, water temperature, wave action, abundance of flooded terrestrial and aquatic vegetation, and the productivity of the nursery areas (Lee and Gleason-Smith 1989).

Following bass and crappie spawning, a drop in water level may expose the spawning nests or subject them to wave action that erode nests or suffocate the eggs by depositing sediment on the abandoned nest. Largemouth bass and crappie are more vulnerable to a drop in water elevation than smallmouth bass because they build their spawning nests in shallower water. While a decreasing water level may also lower water temperatures sufficiently to cause bass to abandon their nests, this problem seems to be more associated with atmospheric drops in temperature as major cold fronts move through following a warming trend (D. Lee, CDFG, pers. com.). When nests are abandoned, eggs and fry are unprotected from predators and the lack of cleaning subjects the eggs to fungus infections.

After the fry leave the nest, shoreline micro-cover of submerged terrestrial vegetation and associated plankton and small invertebrates comprise critical nursery habitat for these young-of-year and the previous year's 1+ year-old juvenile bass and crappie. In many reservoirs, the growth of aquatic vascular plants in the shallows provide summer cover for these young fish as the water level drops. However, Navajo Reservoir has almost no habitat for aquatic plants, and its submerged terrestrial vegetation (both woody and herbaceous) during the early summer is limited to a small amount in the San Juan arm (M. Wethington, pers. com.).

It appears that the submerged rubble of broken rock along much of the shoreline offers the best cover to juvenile bass and crappie in Navajo Reservoir (M. Wethington, pers. com.). In addition, this rubble provides important habitat for the juvenile crayfish that comprise much of the diet of 1+ year old bass. Although juvenile bass are sufficiently mobile to migrate from habitats being exposed by receding water levels, this is not the case with juvenile crayfish. Particularly if somewhat dormant from cold temperatures, losses of juvenile crayfish from receding water levels could be potentially significant to the juvenile bass populations that rely on them for forage (M. Wethington, pers. com.).

The NMDGF believes that water surface elevation decreases of 3 to 4 feet during the May and June bass spawning period will have minimal impacts on the year class success, but that elevation decreases approaching 10 to 12 feet are harmful to bass reproduction (M. Wethington, pers. com.). Mr. Wethington also noted that a strong year class of smallmouth bass every third year appears to provide recruitment sufficient to maintain the existing, good quality smallmouth bass fishery. A literature review showed that largemouth bass and crappie were more vulnerable to spawning impacts from decreasing water levels than are smallmouth bass because of their preference for spawning at shallower depths. It also showed that rising water levels during the spawning period typically does not adversely impact black bass year class strength (Lee and Paulsen Undated; Lee and Gleason-Smith 1989).

Model runs of Navajo Reservoir operations, producing end-of-month water surface elevations were completed for April 30 through June 30, 1973 through 1993. These model runs were for: (1) Baseline Operation (existing conditions with all approved projects and without the ALP Project), and (2) Standard Operation (same as Baseline Operation but with the ALP Project). **Table 4-1** shows the change in the end-of-month water surface elevations with the three operation scenarios. The negative numbers indicate months that experienced a decrease in water level. Although a comprehensive analysis has not been performed to determine if there were significant daily or weekly fluctuations in water levels within a given month, a review of daily elevations for several months all showed a relatively steady increase or decrease in water level through that month. Comparisons of frequency and magnitude of the water surface elevation decreases are provided in **Table 4-2**.

Table 4-2 shows that during this 21-year period there would be nine occasions each in May and June that the Baseline Operation (without ALP) results in a water level decrease. Five of these occasions in each month would be greater than the 4 feet of elevation drop believed to be a possible threshold for adversely impacting bass reproduction. With the ALP Project included, each of these two months would continue to have nine occasions of water level decrease, but only four of these water elevation decrease in each month would be greater than 4 feet. The average water level decrease associated with the period of April 30 through June 30 is one foot less with the ALP Project than without (Table 4-2 [-8.1 vs. -7.1]), and the maximum decrease is virtually the same for these two operations scenarios. The Mitigation Operation results in water elevation decreases were very similar to the other two operation scenarios (see Table 4-2).

It is beyond the scope of this report to fully analyze how the operation of Navajo Reservoir may impact the bass and crappie fisheries of Navajo Reservoir. This will be done in the Navajo Unit Operation EIS. The comparison of the expected conditions with operation for endangered fish and with conditions anticipated with historic operating rules in place, but for development of full project demands (the baseline condition), will require additional data which are not yet available.

Further investigations of the relationship of bass and crappie year class success to water level should relate the reservoir's fluctuation patterns to the NMDGF's annual electrofishing data, crayfish production, ambient air temperatures during the spawning period, and flooding of terrestrial vegetation. Sammons et al. (1999) found that, once suitable spawning temperatures occurred, the initiation of spawning for largemouth bass in a Tennessee reservoir was positively related to the first spring day that the reservoir attained full pool conditions. Several papers note that the protection and feeding of the young-of-year and 1+ year classes of bass often control bass year class strength more than the degree of spawning success (Lee and Paulsen Undated; Lee and Gleason-Smith 1989; Yeager et al. 1992; Sammons et al. 1999).

4.4.3 Navajo Dam Downstream Fisheries in the San Juan River

Seven years of research have been conducted downstream of Navajo Dam to determine the effects of changed operating conditions on the native and non-native fish communities. The results of these studies were used to establish the flow recommendations for the endangered fish (Holden 1999). Final research reports are expected in 2000 for each study. Since the flow recommendations that form the foundation of the change in operation of Navajo Dam are for the benefit of the endangered and native fishery, those impacts have been well addressed.

Table 4-1 Navajo Reservoir Water Surface Elevation Fluctuation, April 30 through June 30, 1973-1993		
	Water Surface Elevation Change (ft)[1]	
	Baseline Operation[2]	Refined Alternative 4 Operation[3]
April 30 - May 31		
1973	7.69	7.56
1974	2.54	2.55
1975	-2.26	-2.26
1976	-0.28	2.62
1977	-4.63	-5.41
1978	9.08	9.02
1979	9.78	9.87
1980	-2.52	-2.52
1981	1.3	1.33
1982	0.76	1.41
1983	-9.11	-9.12
1984	2.1	2.12
1985	0	0
1986	-7.57	-7.57
1987	-1.81	-1.81
1988	-8.64	-8.69
1989	1.61	1.64
1990	6.24	6.42
1991	4.43	4.58
1992	-2.28	-2.34
1993	-0.56	-2.14
May 31 - June 30		
1973	8.73	8.55
1974	-2.9	-2.91
1975	5.54	5.54
1976	-7.59	-4.79
1977	-6.08	-6.49
1978	6.66	6.62
1979	12.85	12.97
1980	5.24	5.24
1981	1.39	1.41
1982	-4.74	-4.72
1983	2.17	2.18
1984	-7.34	-7.37
1985	5.24	5.78
1986	3.35	3.35
1987	3.04	3.04
1988	-12.83	-12.91
1989	-7.25	-7.39
1990	3.44	3.53
1991	-3.49	-3.59
1992	-9.27	-9.57
1993	-0.5	-0.4

Table 4-1
Navajo Reservoir Water Surface Elevation Fluctuation,
April 30 through June 30, 1973-1993

	Water Surface Elevation Change (ft)[1]	
	Baseline Operation[2]	**Refined Alternative 4 Operation[3]**
April 30 - June 30		
1973	16.42	16.11
1974	-0.36	-0.36
1975	3.28	3.28
1976	-7.87	-2.17
1977	-10.71	-11.9
1978	15.74	15.64
1979	22.63	22.84
1980	2.72	2.72
1981	2.69	2.74
1982	-3.98	-3.31
1983	-6.94	-6.94
1984	-5.24	-5.25
1985	5.24	5.78
1986	-4.22	-4.22
1987	1.23	1.23
1988	-21.47	-21.6
1989	-5.64	-5.75
1990	9.68	9.95
1991	0.94	0.99
1992	-11.55	-11.91
1993	-1.06	-2.54

[1] Water elevation change is calculated as the difference between the water surface elevation on the last day of sequential months.
[2] Existing conditions with all currently approved developments including Full NIIP, but without the ALP Project.
[3] Same as Baseline but with the ALP Project.

Table 4-2
Frequency and Magnitude of Water Level Decreases Associated with Operation Scenarios, Navajo Reservoir, April 30 - May 31, 1973-1993

Water Surface Elevation Decrease Frequency:	Mean Decrease (ft)	% Years w/ >4 ft. WSE Decrease	Maximum Decrease (ft)	Year of Maximum
April 30 to May 31, 1973-93				
Baseline Operation[1]: 10 Occasions of monthly WSE decrease; 4 Decreases of > 4.0 feet	-4.0	19%	-9.1	1983
Standard Operation[2]: 9 Occasions of monthly WSE decrease; 4 Decreases of > 4.0 feet	-4.7	19%	-9.1	1983
May 31 to June 30, 1973-93				
Baseline Operation[1]: 10 Occasions of monthly WSE decrease; 7 Decreases of > 4.0 feet	-6.6	33%	-12.8	1988
Standard Operation[2]: 10 Occasions of monthly WSE decrease; 7 Decreases of > 4.0 feet	-6.4	33%	-12.9	1988
April 30 to June 30, 1973-93				
Baseline Operation[1]: 11 Occasions of monthly WSE decrease; 8 Decreases of > 4.0 feet	-7.9	38%	-21.5	1988
Standard Operation[2]: 11 Occasions of monthly WSE decrease; 7 Decreases of > 4.0 feet	-7.6	33%	-21.6	1988

[1] Existing conditions with all currently approved developments including Full NIIP, but without ALP.
[2] Same as baseline ut with the ALP Project.
WSE = water surface elevation

The impacts to the change in hydrology below Navajo Dam on the tailwater trout fishery have been studied, but to a smaller degree. Of specific concern is the impact of reduced flows (250 cfs) on this fishery. In 1996 low flow tests were conducted to examine the impact to the trout fishery during winter months. The results of this study were presented in a Summary Report of the San Juan River Winter Flow Test, November 4, 1996 - March 2, 1997, published by Reclamation in March 1998. The 180-page report documents changes to water quality, hydrology, endangered fish, trout fishery, riparian and wetland vegetation and wintering waterfowl. The following is an excerpt from the executive summary discussing the impact of reducing outflow to 250 cfs on the trout fishery:

> *The direct effects of the reduced winter flow test on the San Juan River trout fishery was a 24 percent reduction in habitat between Navajo Dam and Texas Hole. Habitat was minimally affected from Texas Hole down to the end of the special regulation water. There was some loss of macroinvertebrates in the dried portions of the river. Overall macroinvertebrate densities declined between October and March by about 36 percent. It is uncertain how much the flow test contributed to this decline because similar reductions have occurred seasonally between the fall and spring in the San Juan River. These effects were apparently not severe enough to adversely affect the trout population. Trout*

continued feeding and did not move downstream searching for food or habitat. There was no evidence that the extended reduced flow caused a detrimental effect on the health of the trout fishery although small trout had better body condition factors than large trout. Fish stomach analyses showed no predation of small fish by large trout; trout continued feeding throughout the study and the mean stomach fullness was variable. No dramatic changes occurred in water quality in the tailwater during the four-mount test. Water temperatures were lower than during other seasons, but were consistent with normal winter temperatures. Angler pressure was similar to the previous winter, but both years were up dramatically compared to earlier years. During the test period, 70 percent of the angler pressure was between the dam and Texas Hole.

Impacts of high flows on the tailwater trout fishery were studied as a part of the SJRBRIP research in 1992 and 1993, the results of which are summarized in two annual reports of the research (SJRBRIP 1993 and 1994). The results of all these studies will be incorporated into the Navajo Unit Operation EIS and, if necessary, additional data collected to fill gaps that may be identified.

4.5 Cultural Resources (archaeology, ethnology, paleontology, historical)

The re-operation of Navajo Dam will change the flow regime in the San Juan River and the operational water level in the reservoir. Since the average water surface elevation will be higher with the new operating regime than occurred historically and the overall range is the same, no impact is expected upstream of the dam. Downstream of the dam, riverbank cultural resources could be impacted by a change in flow patterns. Potential cumulative impacts would include impacts to upland cultural resources from increased recreational use and traffic.

In connection with the Resources Management Plan and EIS for the Navajo Unit Operation (in preparation), cultural resources evaluations are underway to: (1) define cultural resource baseline conditions, (2) conduct alternative appraisal analyses, (3) perform potential impact assessments, and (4) develop any necessary planning and compliance measures needed for mitigation or treatment.

4.6 Geology and Soils

Since reservoir levels are within the range of historic operation, no impact is expected to geology or soils upstream of the dam. Increased frequency and magnitude of high flows downstream of the dam will increase bank erosion and sediment transport in the system, restoring more of the natural function of the river.

4.7 Hazardous Waste

There are no construction activities associated with the proposed action, so no hazardous waste will be generated. There is no change in the range of reservoir levels from historic operation, so no upstream effects are expected. The increased flood frequency and magnitude downstream of Farmington, New Mexico could impact oil well sites within and adjacent to the floodplain. Some additional data collection may be necessary. This potential impact will be assessed in the Navajo Unit Operation EIS.

4.8 Environmental Justice and Indian Trust Assets

Application of these operating conditions affects the water rights of the Jicarilla Apache, Southern Ute and Ute Mountain Tribes and the Navajo Nation. If Navajo Reservoir was not operated to meet the new flow recommendations for the San Juan River, it also affects compliance with the endangered species act, with particular significance to the Colorado pikeminnow and razorback sucker. Adequate data exist to assess these impacts, and it will be analyzed and addressed in the Navajo Unit Operation EIS.

4.9 Land Use

Changes in the fluctuation of Navajo Reservoir water surface elevation may impact land use around the reservoir, but these should be minor since the change is small. The ability to deliver water to new agricultural lands made possible by this operation will affect the use of these newly irrigated lands. Some options may impact the use of land in the riparian zone downstream of Navajo Dam.

4.10 Recreation

Access to the trout fishery below the dam may be impacted by both the high water during peak runoff and the low water during base flow (non snowmelt runoff period). Some impact may occur to the sport fishery below the confluence with the Animas River, but it will be minor. Some campgrounds that are in the active flood zone of the river may also be impacted by the increased frequency of high flow. Altered reservoir levels may affect the use of marinas and parks around Navajo Reservoir, but the small change in elevation should minimize this impact. Mooring locations at the marinas may be affected, but there should be no change in the magnitude of boating and fishing in the reservoir. Recreational rafting conditions in the San Juan River will be improved during high flow times. Maintenance of minimum base flow in the lower river will improve rafting during summer months that have historically experienced periods of flows below 500 cfs. These concerns will be further evaluated and addressed in detail in the Navajo Unit Operation EIS.

4.11 Safety

The major impact to safety occurs during the period of elevated releases. These higher water levels can be more dangerous to fisherman, rafters and other recreational users of the river. Existing data are adequate for this resource area, and it will be addressed in the Navajo Unit Operation EIS.

4.12 Socioeconomics

The operation of Navajo Reservoir requires no construction, so there will be no economic benefits from construction activities. This preliminary assessment of the effects on flatwater and riverine fisheries indicates there will be no significant change in boating and fishing associated with the operation of Navajo Reservoir. Therefore there will be no impacts to recreation economics. There will be a positive impact to the economy of the region from the additional water development that is allowed as a result of operation for the benefit of endangered fish. A detailed assessment of the effect of the operation on recreation, agricultural and other water use economics will be conducted and addressed in detail in the Navajo Unit Operation EIS.

4.13 Endangered Species

Operation of Navajo Reservoir to mimic a natural hydrograph is an action being taken to benefit the downstream endangered fishes. Impacts to the southwest willow flycatcher include the change in the hydrologic regime and the subsequent impact on their habitat, both above and below the dam. The NIIP Biological Assessment addressed changes in flow below the dam and concluded that there would be no adverse effects to any endangered species, including the southwest willow flycatcher from operation of Navajo Dam to meet flow recommendations.

A new list of endangered species that could be impacted would be obtained prior to completing the Navajo Unit Operation EIS. While no impacts are anticipated, any specific concerns around the reservoir not previously addressed would be considered in evaluating data collection requirements and the impact to all endangered species addressed in the EIS and associated ESA Section 7 consultation.

4.14 San Juan River Water Quality

The only major anticipated effect is a change in downstream water temperatures. Adequate data exist for evaluating this concern, and it will be addressed in the Navajo Unit Operation EIS.

4.15 Riparian/Wetland Habitat

Downstream of Navajo Dam, the new operating conditions may increase wetland areas during high flows. The elevated spring flows will return the system to a more natural-like condition with less stable banks and a more dynamic riparian area. During low flows, the impact is expected to be minimal based on results of the San Juan River Winter Flow Test (Reclamation, 1998)

Upstream of the dam, changes in reservoir water surface elevation fluctuations could impact wetlands. Adequate data exist for assessing this resource area below the dam. Upstream data need to be developed and assessed. This will be addressed as part of the Navajo Unit Operation EIS.

4.16 Wildlife

The changes in downstream flow regimes could impact nesting waterfowl. Other impacts are expected to be minor or non-existent. A similar effect could occur upstream from changes in Navajo Reservoir water elevation. Adequate data exist for assessing this resource area below the dam. Upstream data need to be developed and assessed. This will be addressed as part of the Navajo Unit Operation EIS.

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Personal Communications %

Gustaveson, Wayne. Utah Division of Wildlife Resources. %

Wethington, Mark., New Mexico Department of Game and Fish. %

Appendix A

Limnology Figures A-1 through A-8

Figure A-1
Navajo Reservoir Seasonal Temperature Profiles
Near Dam, September 1990 to August 1991

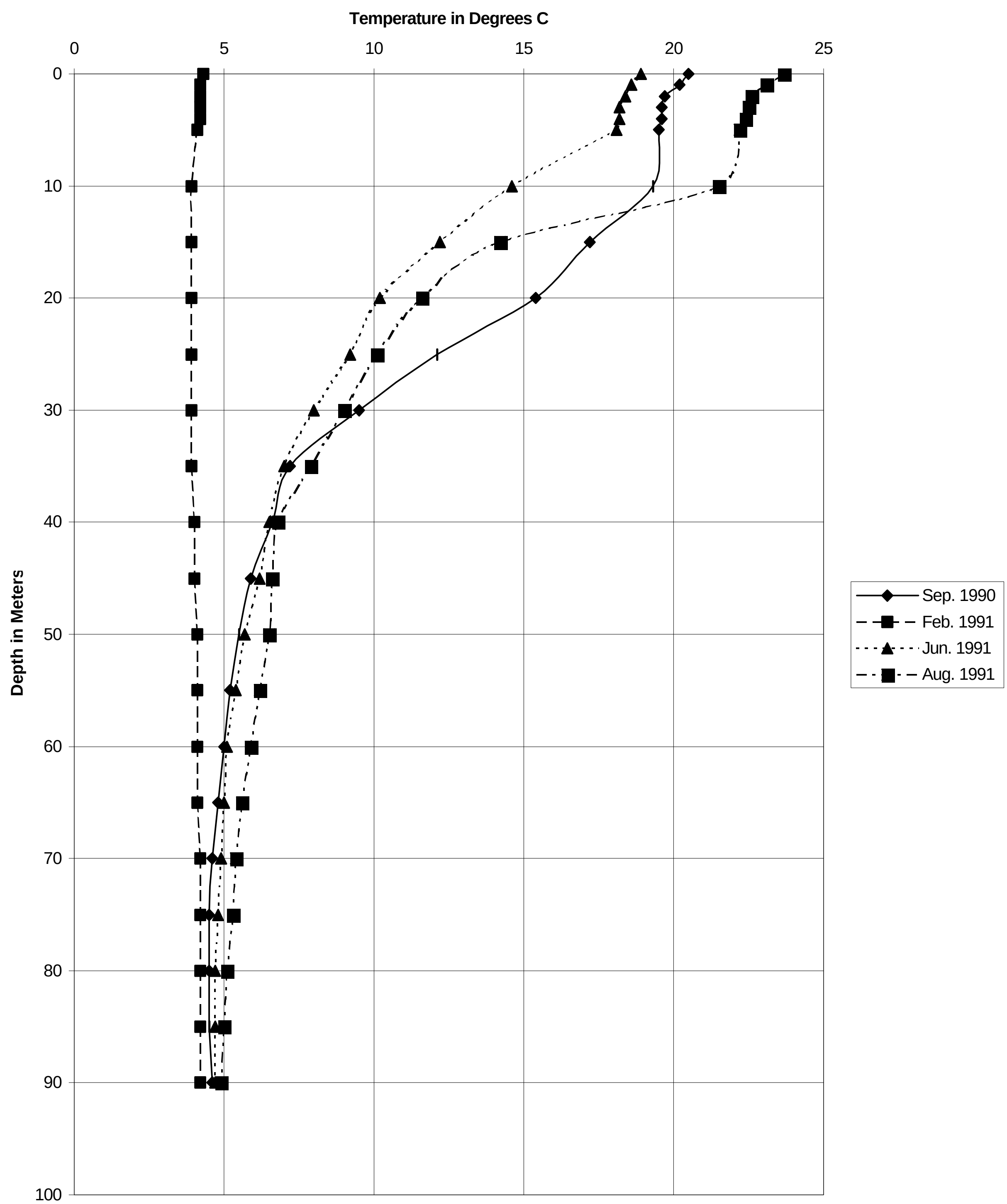

Figure A-2
Navajo Reservoir Seasonal Dissolved Oxygen Profiles
Near Dam, September 1990 to August 1991

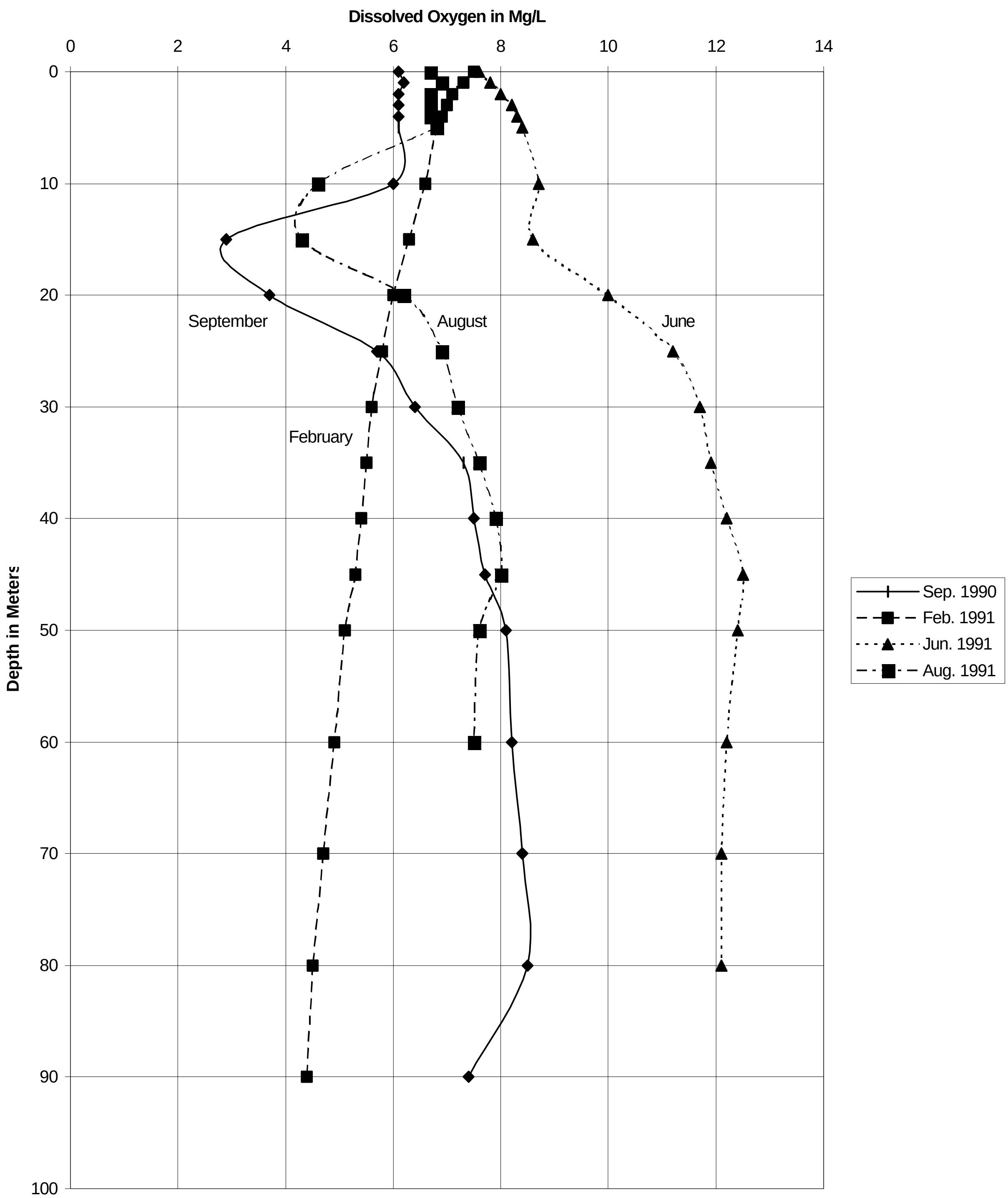

Figure A-3
Navajo Reservoir Seasonal Temperature Profiles
France Canyon Arm, September 1990 to August 1991

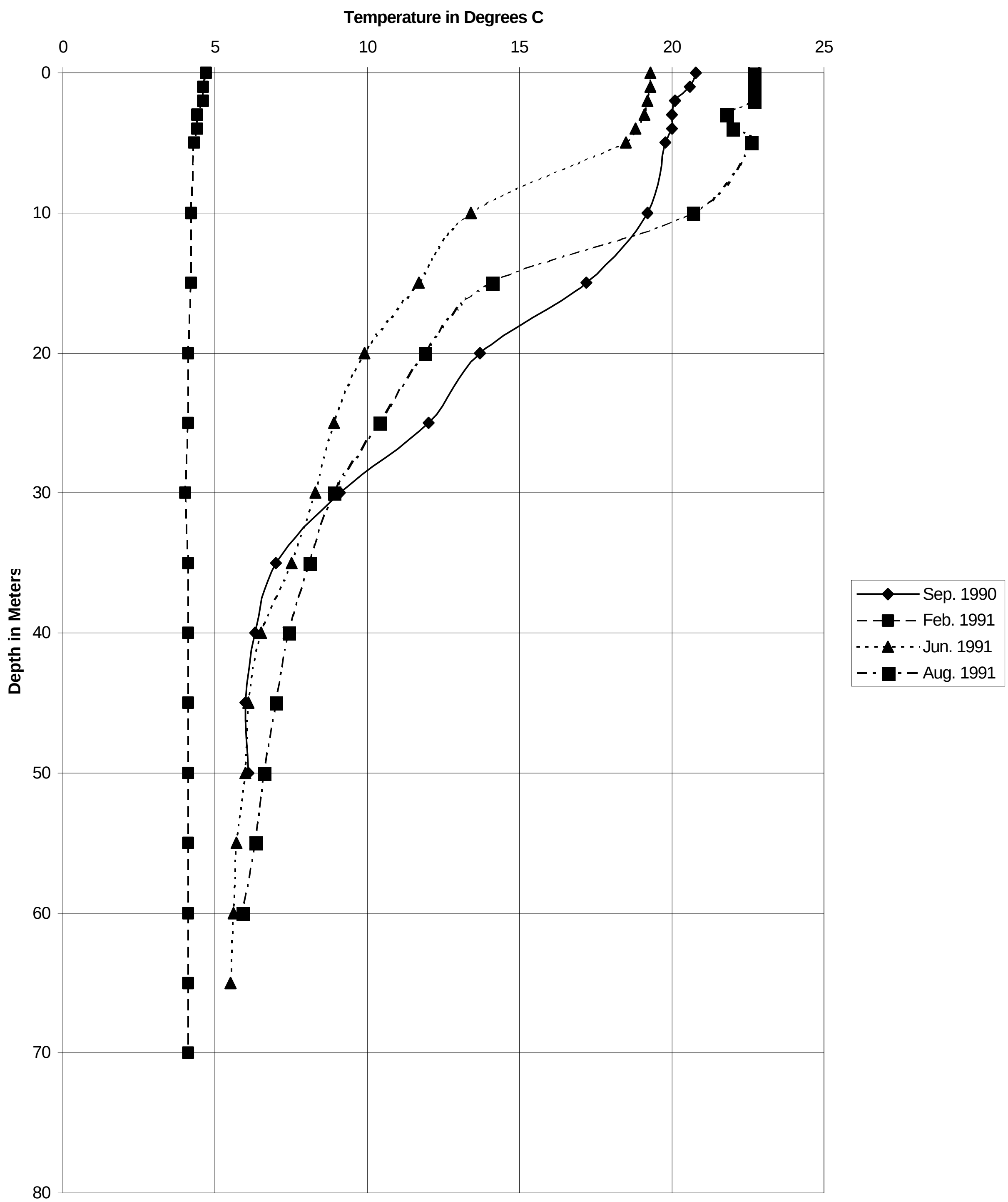

Figure A-4
Navajo Reservoir Seasonal Dissolved Oxygen Profiles
Frances Canyon Arm, September 1990 to August 1991

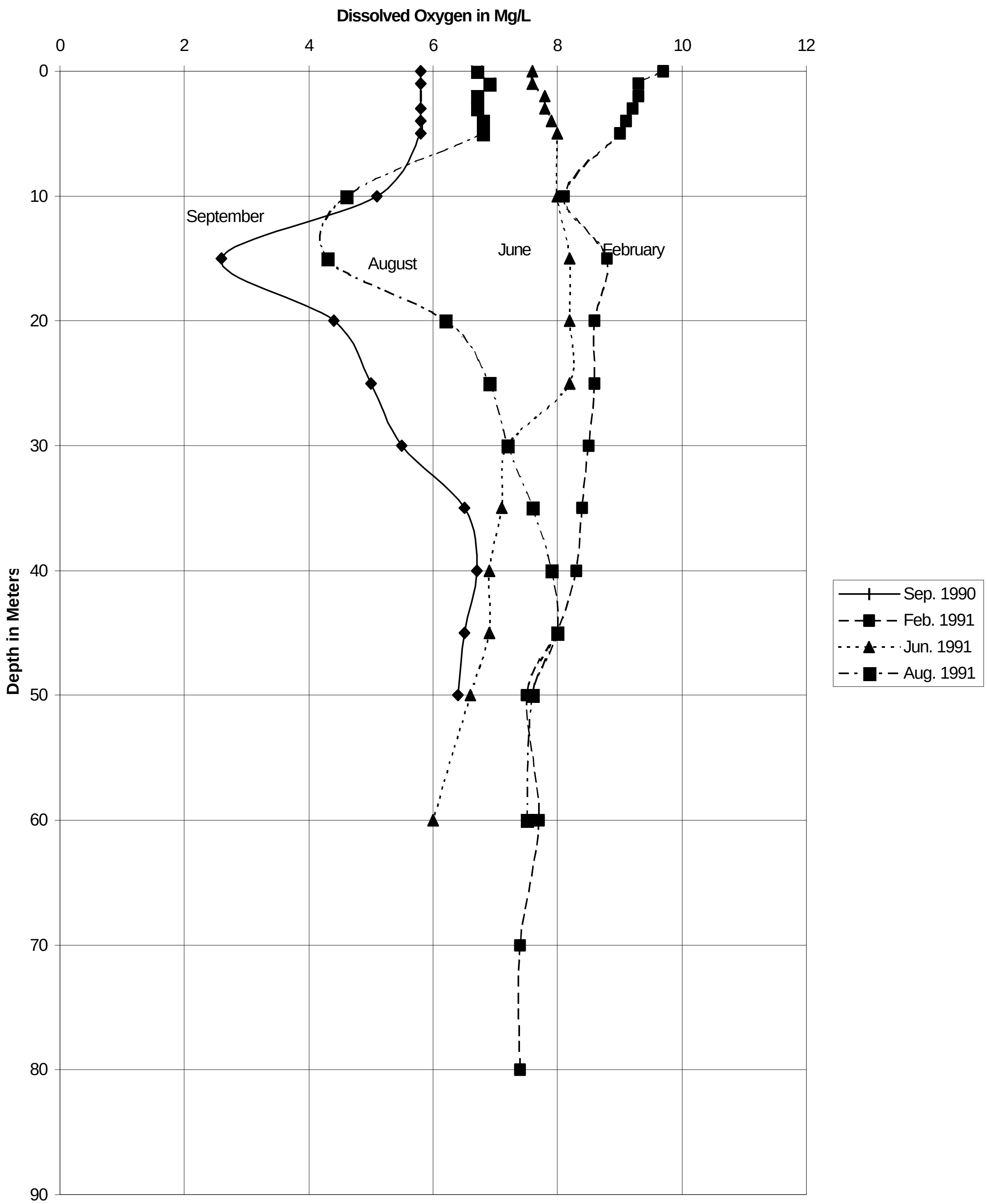

Figure A-5
Navajo Reservoir Seasonal Temperature Profiles
Pine River Arm, September 1990 to August 1991

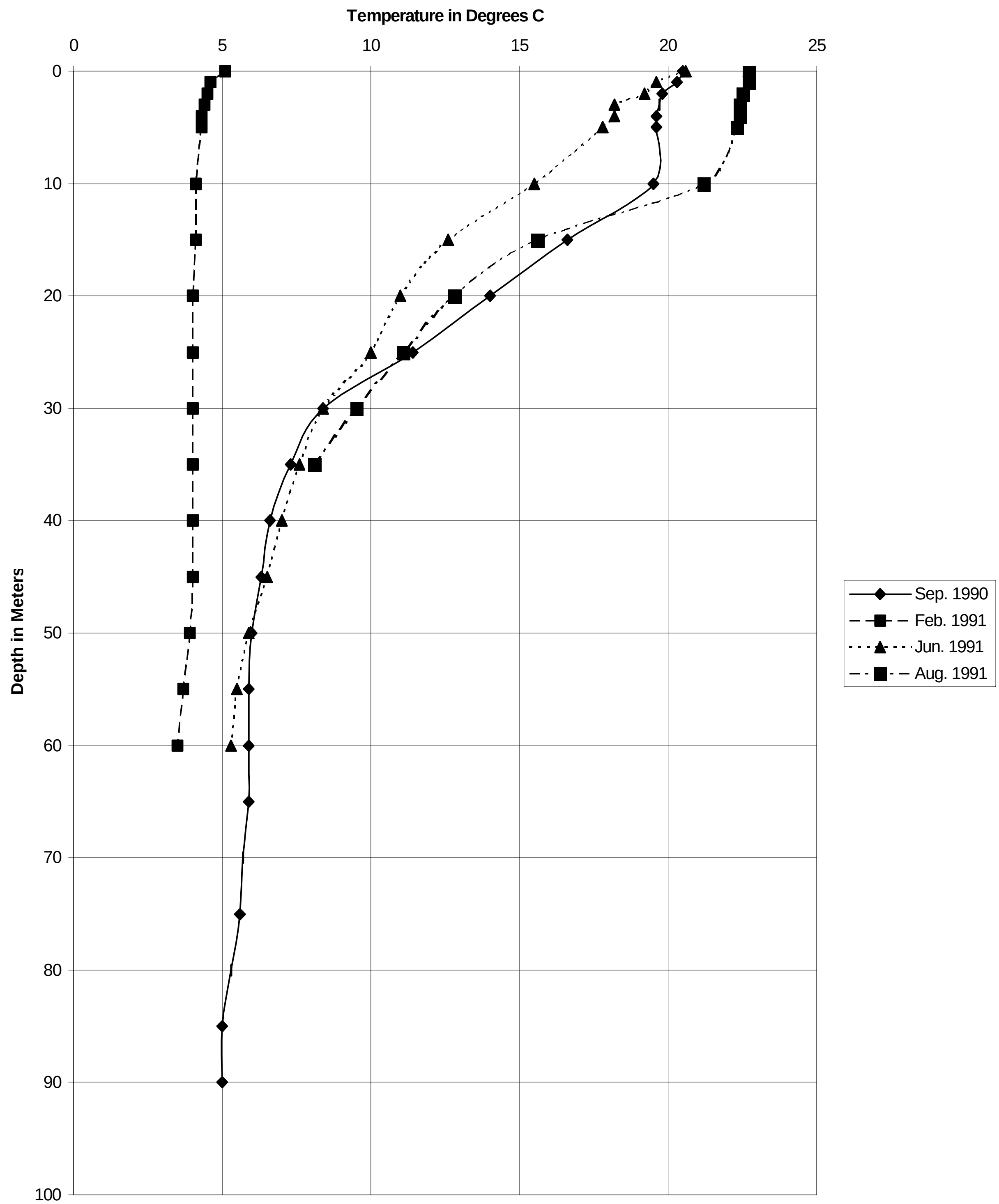

Figure A-6
Navajo Reservoir Seasonal Dissolved Oxygen Profiles
Pine River Arm, September 1990 to August 1991

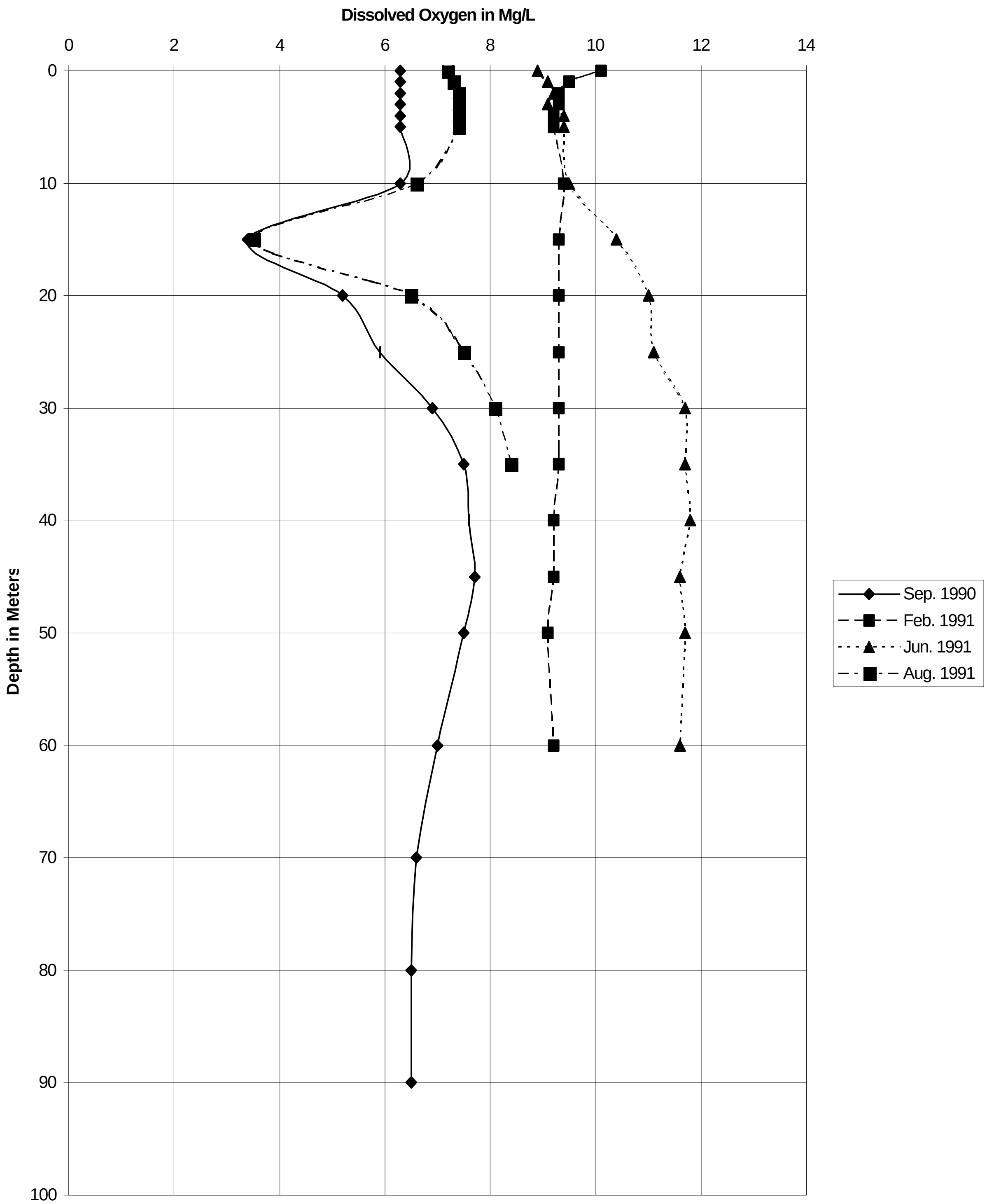

Figure A-7
Navajo Reservoir Seasonal Temperature Profiles
San Juan Arm, September 1990 to August 1991

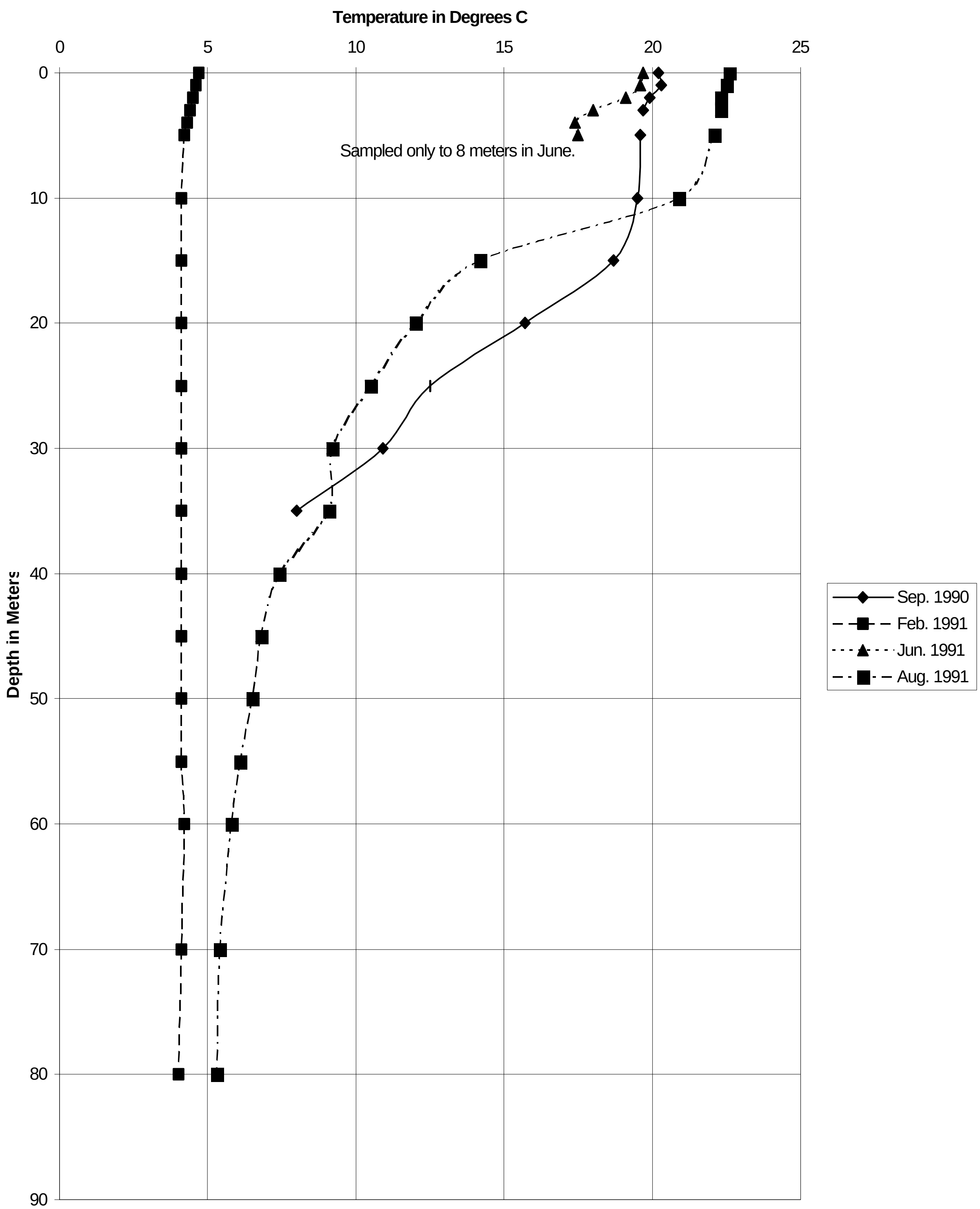

Figure A-8
Navajo Reservoir Seasonal Dissolved Oxygen Profiles
San Juan Arm, September 1990 to August 1991